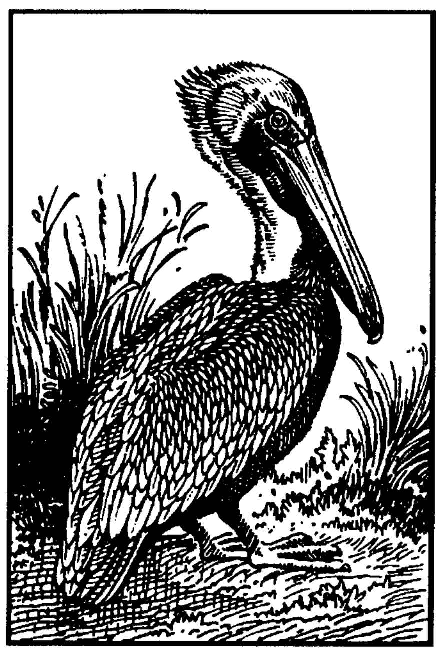
US Army Corps of Engineers
Waterways Experiment Station

Wetlands Research Program Technical Report WRP-RE-5

Native Plant Material Sources for Wetland Establishment: Freshwater Case Studies

by U.S. Army Engineer Waterways Experiment Station



August 1995 – Final Report

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Wetlands Research Program

Technical Report WRP-RE-5
August 1995

Native Plant Material Sources for Wetland Establishment: Freshwater Case Studies

by U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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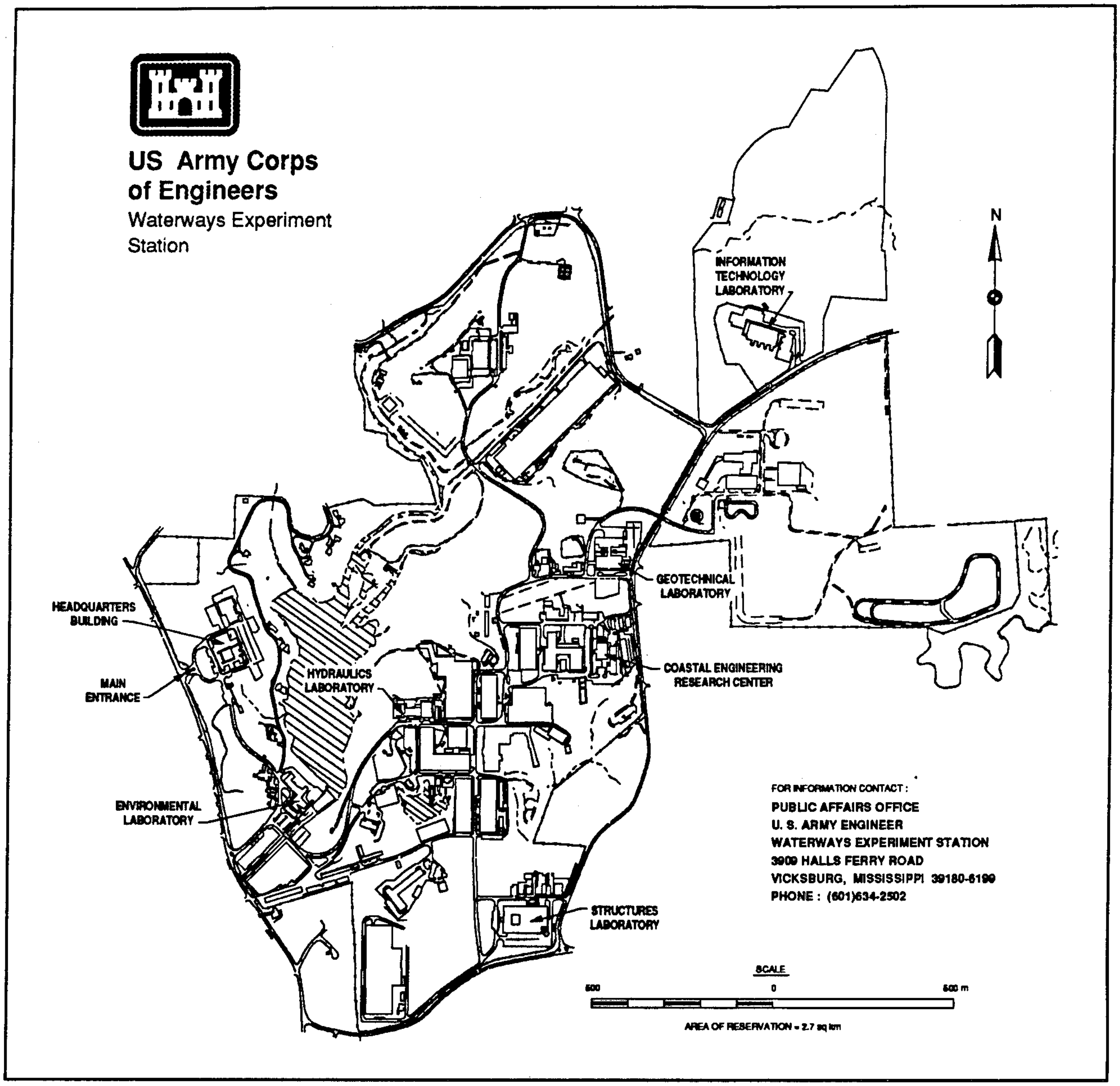

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Wetland Restoration

Native Plant Material Sources for Wetland Establishment: Freshwater Case Studies (WRP-RE-5)

ISSUE:

The establishment of vegetation in created or restored wetlands often requires the acquisition of plant material that is similar to local wetland vegetation. Two sources of vegetation, commercial and field collected, offer different advantages and disadvantages for various wetland project conditions. Although information about commercial plant material sources is available from suppliers, little information is available about handling field-collected plant material.

RESEARCH:

Primary objectives of this report are to present information on the advantages and disadvantages of commercial versus native sources of plant material, and guidance for protecting collection sites. In addition, three wetland case studies are presented that successfully utilized plant material collected from natural wetlands.

SUMMARY:

Wetland plant material can be successfully used in wetland restoration and creation projects to rapidly establish diverse vegetation that is adapted to local conditions. Plant material should preferably be salvaged from wetlands to be destroyed; otherwise, care must be taken to minimize disturbance to collection sites. Wetland plant material can be collected as seeds, whole plants, or portions of plants. An advantage of natural plant material over commercial sources is that plant-soil transfer techniques not only help increase plant species richness, but other desirable material is also transferred. Plant-soil transfers inoculate the new wetland with microorganisms and fauna that may aid in the development of wetland functions and values.

AVAILABILITY OF REPORT:

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About the Authors:

This is a WES compiled report. Contributing authors are: Dr. Mary M. Davis, a wetland ecologist at the WES Environmental Laboratory; Dr. Gary Wein, an ecologist at the Savannah River Ecology Laboratory; Kevin L. Ervin, Paul A. Fishman, and Christie Galan, restoration ecologists, and Mark G. Wilson, a horticulturalist, serving as consultants/contractors. Point of contact is Dr. Davis at (601) 634-2853.

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Wetlands Restoration, Protection, and Establishment Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32761, "Wetlands Field Demonstration and Research," for which Dr. Mary C. Landin was the Technical Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work.

Dr. Dave Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitors' Representative; Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the Wetlands Research Program Manager. Dr. Landin, Environmental Laboratory (EL), WES, was the Task Area Manager.

The research was performed under the direct supervision of Dr. Mary M. Davis, EL. The L-Lake, Charlotte County, Correctional Institute and West Eugene Wet Prairie case studies were demonstration sites of the WRP. The study was conducted under the general supervision of Dr. John Keeley, Director, EL; Dr. Conrad J. Kirby, Chief, Ecological Research Division (ERD), EL, and Mr. Ellis J. Clairain, Chief, Wetlands Branch (ERD). The design and construction of the individual case studies presented in this report were privately funded as wetland mitigation projects. The initial work was directed by personnel of the Savannah River Ecology Laboratory (SREL, Case Study #1); Kevin L. Ervin, Consulting Ecologist, Inc. (KLECE, Case Study #2); and Fishman Environmental Services (FES, Case Study #3). The final report was written by Dr. Davis, WES; Dr. Gary Wein, SREL; Dr. Gary Pierce, SREL; Mr. Ervin, KLECE; Mr. Robert Rutter, KLECE; Mr. Paul Fishman, FES; Mr. Mark G. Wilson, FES contractor; and Ms. Christie Galen, FES.

At the time of the publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Introduction[1]

Background

A primary objective in many wetland restoration projects is to establish vegetation that is similar in structure and composition to natural wetlands. Plant species lists developed from local reference wetlands are used as guidelines for desired vegetation in the project wetland. If the existing vegetation on the project site does not have adequate numbers or abundance of desired species, additional vegetation must be obtained.

The two basic sources of wetland vegetation are commercially grown plant material and native plant material collected from naturally occurring populations. There are benefits and drawbacks for each plant material source. The project manager must consider many factors such as availability and cost of obtaining the plant material when deciding which source is appropriate for the wetland restoration project. While information about commercially grown plants is readily available from the industry, relatively little guidance exists for use of native plant materials. The objectives of this report are to discuss conditions under which it is appropriate to use native sources of plant material and to present three case studies that demonstrate techniques for collecting and establishing wetland vegetation from natural sources in wetland restoration and establishment projects. Information about substrate preparation, hydrology, and other aspects of wetland restoration projects is beyond the scope of this report, but is available from sources such as Soil Conservation Service (SCS) (1992), Hammer (1992), and the forthcoming wetland engineer manual.

Native Versus Commercial Sources of Plant Material

The ultimate source of all plant material (i.e., seeds, rhizomes, stem cuttings, etc.) for wetland restoration is from plant populations growing in wetlands. The difference between native and commercial sources of plant

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[1] Written by Dr. Mary M. Davis, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

material for wetland restoration is how the material is handled after collection from native wetlands. Plant material growing in native wetlands can be collected and used directly in wetland restoration projects. Alternatively, plant material collected from native wetlands can be treated and made available commercially. For example, sedge rhizomes collected from a native population can be grown in a nursery, and the number of individuals increased that are suitable for planting. Also, seeds collected from native wetland trees may be germinated and grown to an appropriate size using standard horticultural techniques in a nursery before planting in a wetland restoration project. These examples illustrate that commercial treatment can optimize the use of plant material collected from native populations by increasing the number and establishment rates of the plants.

The choice of native, commercial, or a combination of plant material sources for a wetland restoration project depends on many trade-offs (Table 1). In general there is more control over the timing, quality, and quantity from commercially available plant material than from native sources.

Table 1
Advantages and Disadvantages of Using Native and Commercially Grown Plant Material in Wetland Restoration Projects

Attribute	Native	Commercial
Diversity	Vegetative stock - similar to native system Collected seed - similarity depends on season of collection Seedbank - usually not similar to native system	Vegetative stock and seeds - limited to available stock
Ecotypes	Similar to native systems	Limited by source material and occurrence of local growers
Availability	Limited by degree of disturbance to donor site, abundance of target species, occurrence of wetlands to be destroyed with salvageable plant material, and knowledge of species handling requirements	Usually good for widely distributed species Other species limited by source material and knowledge of species-handling requirements
Establishment success	Good with adequate hydrology	Good with adequate hydrology
Cost	Based on equipment and labor to collect, transfer, store, and plant the material	Based on purchase and shipping prices plus equipment and labor to store and plant the material
Quality assurance	Limited resource for replacing damaged material	Supplier responsible for quality of plant material when it arrives on site
Miscellaneous	Rapid establishment of diverse plant cover has been successful in limiting encroachment nuisance species	Limits damage to local wetlands by irresponsible plant collectors

Given proper notice, commercial growers can often supply ample quantities of good quality plant material to the project site at the time of planting. Depending on the type of plant material and availability of native sources, the cost of commercial plant material may compare favorably on a per plant basis with native plant sources. In addition, no plant handling expertise or labor is required to deliver the plants on site.

Native plant material sources, on the other hand, are likely to provide a suite of species similar to reference wetlands and diverse genetic stock that is adapted to local conditions. If a salvageable source of native plant material is available, ample material can be easily obtained to rapidly revegetate project wetlands. The rapid establishment of diverse vegetation is desirable for many reasons, including a limited potential for colonization by aggressive undesirable species. Caution must be exercised, however, that native plant material be salvaged from wetlands to be developed. It is the project designer's responsibility that unethical collection sources and methods are not used.

Handling Native Wetland Plant Material

There are four basic periods during which plant material is handled for wetland restoration projects: collection, storage, shipping, and planting. Many of the techniques used for handling commercial plant materials apply to native plant materials. Shipping is not usually a problem when native sources of plant material are used because local transportation times are limited. Additional techniques and cautions for collecting, storing, and planting native plant material are presented below.

A variety of types of native plant material can be collected. Seeds, whole plants, stem cuttings, rhizome cuttings, and plant-soil transfers offer benefits that can be utilized in different planting situations. An advantage of using native sources of plant material for wetland restoration is the opportunity to transfer not only diverse plant material, but also associated soil fauna and flora that may facilitate wetland development. Where the opportunity exists, plant materials should not necessarily be thoroughly separated from nontarget species and soil prior to their transfer to the project wetland. As long as caution is used not to transfer aggressive undesirable species, the transfer of additional plant and soil material is beneficial for the project wetlands.

Seeds

Seed stock from native sources differs from commercially available stock primarily in the degree of purity and estimated viability. Pure seed stocks of target species can be collected by hand from individual plants or harvested from large pure stands (see Case Study #3 in Chapter 4). Seeds from trees can be caught on sheets placed under the tree during the appropriate season. Once the collected material is cleaned and checked for viability, this seed stock is similar to commercially supplied stock.

Seeds can also be collected on a community basis from all portions of the habitat such as from the plant, litter, soil, or water surface. This results in a diverse species mixture that may be desirable when a diverse plant community is a project objective. To maximize the representation of species that produce seeds at different times during the year, seeds should be collected during several seasons. If seed collection can be made only once, collections during the late fall or early winter is mostly likely to contain at least some seeds produced in the spring, summer, and fall. Local plant experts or plant manuals may provide guidance for when to collect seeds of desirable species. Standard seed storage techniques should be used until the seeds are required for planting.

A primary advantage of native collected seed stock is control over collection site locality and conditions. As is true for all plant material for restoration, the closer the collection site conditions are to the project site conditions, the better the likelihood of successful plant establishment. Seeds should be collected from plants growing in conditions similar to the project wetland. To obtain diverse genetic stock, it is preferable to select several donor plants in several locations. In addition, seed collections from native populations of target species allow for increased species richness in the project wetland. Seeds of species that are not readily available from commercial sources can be collected from local wetlands.

Caution should be exercised so that undesirable species are not transferred to the wetland restoration project site. Weedy and aggressive species have widely distributed seeds that can be inadvertently collected with seeds of desirable species. While some weedy species may be helpful by rapidly becoming established and increasing species diversity, aggressive species that become monocultures and retard development of desired species should usually be avoided. Germination trials should be run on samples of seed stock prior to planting on the restoration site. Seeds of undesirable species can be separated from the mixture if they comprise a relatively small proportion of the mixture and have a distinctive size, shape, or density.

Whole plants

Whole plants are commonly dug from native wetlands to be planted in wetland projects (see Case Study #1 in Chapter 2). Procedures for digging plants from native wetlands do not differ significantly from standard horticultural methods. Since root systems of many wetland plants are usually near the soil surface, digging these plants is often simple. Some species of emergent vegetation (e.g., *Nelumbo*) are important exceptions, however, that can have deep root systems that are difficult to harvest. In addition, plant collections from wetlands when standing water is present may be difficult due to problems locating and handling the plants. Access for trucks or boats must be well planned so that the plants can be transported out of the source wetland with minimum impacts to the donor area.

Plants of all but the largest sizes and growth forms have been successfully transferred. The success of transfers often depends on the amount of root mass in relation to stem and leaf mass being transferred. If an inadequate amount of intact roots is taken with the plant, especially woody plants, the plant will be stressed by reduced capacity of water uptake by the roots. Survival of the stressed plant then depends on the rapid replacement of roots. Successful transfers of large trees are usually limited by the inability to obtain a large enough root mass. Whole trees and shrubs that spread by rhizomes are also difficult to transfer due to the relatively small root mass associated with each stem and the difficulty in digging up an intact plant.

Small whole plants are most easily transferred, and individual plants are usually taken. However, large individuals of grasses, grass-like, and bulbous species can often be subdivided into several individuals. Care must be taken so that an adequate amount of roots remains in good condition and well attached to the stem as the parent plants are being separated. If necessary, shoots of large plants or plants with small root-to-shoot ratios should be trimmed to make them easier to handle and reduce water stress. In addition, trimming plants may minimize breakage during transport.

The collection of plants should be timed to minimize storage time before transplanting. Transplanting is generally most successful during cooler parts of the year when soil water is not limiting. Heat increases rates of water loss from plants. Consequently, transplanting during the summer greatly stresses plants, particularly large plants. Water loss stress of the transplanted individuals can be reduced by trimming aboveground portions of the plant. Collections should be made, therefore, during cool times of the year, preferably when plants are dormant and/or small.

In addition, transplanting when ample soil water is available will help minimize plant stress. Too much water, however, stresses transplanted wetland plants that are not able to get oxygen to their roots or produce roots in anoxic soils. Therefore, plant collections should also be timed to coincide with relatively low water levels in the recipient wetland. The desired water level depends on the types of plants being transferred. Herbaceous wetland plants, particularly plants with spongy stems and roots (e.g., *aerenchyma*) are commonly able to become established in standing water as long as some portion of the leaves are exposed to the air. Woody shrubs and trees have more limited capacities to oxygenate their root zones and to produce roots in anoxic soils. Consequently, they also have better survival and growth rates when planted in drained soils.

Stem cuttings

Stem cuttings for wetland restoration are usually taken from woody species that root easily (e.g., red-osier dogwood, various willows) while the plants are dormant. The cuttings can be inserted directly into the ground (roughly 1/3 above ground and 2/3 below ground), bundled into wattles, or pinned to the ground for a variety of applications (Allen and Klimas 1986). Cuttings should be small enough that the new individual can be supported by the adventitious roots that will develop along the stem. Stem cuttings less than 5 cm (2 in.) basal diameter and 3 m (9 ft) long have been used successfully in many areas. However, poles greater than 4 m (12 ft) with diameters up to 10 to 12.5 cm (4-5 in.) have been used in Illinois and Idaho.[1]

Collection of stem cuttings should be timed with availability of storage facilities and conditions at the recipient wetland. Stem cuttings must be kept cool enough to maintain dormancy until planting. Cuttings that are allowed to sprout prior to planting are less successful at developing root systems because stored energy was wasted. Cuttings must also be kept moist during storage, or they will die. Stem cuttings can be stored under cool, moist conditions for several months. Cuttings should be planted when conditions are good for growth because they can dry out or be frozen back if placed out too early in the year.

Rhizome cuttings

Rhizomes are underground stems. Many rhizomatous perennial species (e.g., *Scirpus validus*, *Typhus* spp.) are capable of resprouting from pieces of rhizome that contain at least one meristem or node (i.e., the point where the leaf is attached to the stem). Rhizomes can be collected and cut into several pieces, often 5 cm (2 in.) or greater in length, that will each develop into an individual plant. It is not necessary to collect leaves or roots with the rhizome. If stored properly under cool, dark, and moist conditions, planted rhizome cuttings will readily sprout new stems and roots.

Many of the considerations for collecting small whole plants also apply to collecting rhizome cuttings. Rhizomes should be collected at such time that storage periods can be minimized before conditions at the recipient wetland site are good for growth.

Plant-soil transfers

A unique advantage of collecting plant material from native wetland sources in comparison with commercial plant material sources is the capability of taking whole complexes of wetland plant species that natively grow together. These plant associations can be taken from areas that closely match the recipient wetland site conditions. An important addition to the transfer of plants is the potential to transfer upper horizons of the wetland soil that may contain organic matter, fungi, invertebrates, and other organisms. These additional transfers "inoculate" the new wetland and may accelerate development of a functional wetland ecosystem.

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[1] Personal Communication. (1994). Hollis Allen, biologist, Vicksburg, MS.

Plant-soil transfers are made in two basic forms that are either intact or a "mulch." Both forms involve collecting the upper layers of plants and soil from a donor wetland and placing the material in the recipient wetland site. Mulching involves scraping up donor wetland material and spreading it over the surface of the recipient wetland (see Case Study #2 in Chapter 3). This may entail large quantities of material handled with large machinery. Since the donor wetland can be severely disturbed, this method should only be utilized when the donor wetland is to be otherwise destroyed, and the material can be salvaged. Various sizes of intact portions of donor wetland substrate can be collected that can have more limited extents of disturbance than collecting mulch. Both intact and mulch plant-soil transfers are most successful when the material is stored for as short a period of time as possible, and preferably transferred directly to the recipient site.

Mulching has the advantage of rapidly moving whole communities of plants and associated animals to the new wetland site. If conditions are good for growth at the receiving wetland, diverse plant communities can rapidly become established. Further, the addition of organic matter to the new wetland can provide beneficial soil nutrients and water holding properties to the project. Several limitations to mulching, however, must be carefully considered during project planning to ensure successful transfer of living material. First, timing of the availability of the material with the wetland restoration project schedule is important so as to eliminate or minimize stockpiling time. The mulch contains living organisms and other organic materials that are easily degraded with heat and moisture loss. Changes in exposure to oxygen and light also affect the mulch contents. Plants buried for too long in stockpiles will die and rot; seeds will lose viability; animals may suffocate; and the availability of nutrients will be altered. Another problem associated with stockpiling is the area impacted under the pile itself. It is preferable to move the mulch material directly from the donor to the recipient wetland. If necessary, however, mulch piles should be stored outside of wetlands (Garbisch 1986) for as short a duration as possible to minimize impacts on the storage area.

Mulching should be used with caution because when the mulch is moved the buried seedbank is exposed. Weedy species often comprise a large portion of many wetland seedbanks (Leck 1989). These seeds germinate when exposed and may cause problems if they are aggressive and abundant. Caution should be taken to check seedbank contents of the intended donor wetland mulch to determine whether weeds will be transferred to the new wetland site.

Small plugs are commonly utilized to transfer intact wetland plant material from donor marshes and swamp ground surfaces to wetland restoration sites. Coring devices can be used to lift the plant and soil material out of the ground. The size of the core depends on the target plants. Cores 5 cm (2 in.) in diameter can be used to transfer grass plugs. This method has been used, for example, in *Spartina alterniflora* coastal marshes where the grass forms thick mats. Larger cores can be used if necessary to transfer more species. Plugs can be collected with no more formal equipment than a shovel and bucket. Plants dug from swamps can be transferred to newly planted swamps to help increase diversity at a relatively low cost (Clewell and Lea 1990). It should be noted, however, that weight of the plugs can quickly become a limiting factor to the plug size used. In addition, plugs may not remain intact during digging and transfer if there is not enough clay or organic matter to hold the plug together.

Sodmats are a form of an intact plant-soil transfer method that has been successfully used in different regions of the country. A large piece of intact wetland substrate, as large as 2.7 m (8 ft) square and 20 cm (4 in.) deep, is cut from the wetland with shovels and a front-end loader, moved onto a plate, and transferred to the recipient wetland. The sod pieces, modified with a sharp-edged steel plate, are placed in matching hydrological conditions from where they came and fit back together in a similar manner as sodding a yard (see Case Study #3 in Chapter 4). The entire plant aerial and root systems are taken. Shrubs and small trees can be moved intact with good survival rates.[1] Best results are achieved if the soils are moist but well drained at the time of cutting. This reduces weight, helps the mat stay intact, and reduces "sticking" of the mat as it is being transferred on and off the transfer plate. Since relatively large areas of the donor wetlands are impacted by this method, it should be used primarily as a salvage technique as is recommended for the mulching technique.

Sources of Native Wetland Plant Material

Native sources of wetland plant material have many advantages over commercial sources that may make them the best choice for revegetating a wetland restoration project. Ready access to desirable species that are adapted to local conditions is particularly important in regions of the country in which few commercial growers are located.

However, a major disadvantage for using native plant sources is the potential for disturbance to donor wetlands. The removal of plants potentially eliminates one or more species from the donor wetland. Access through the wetland by truck or heavy foot traffic compresses soils and affects drainage patterns. Runoff from heavily disturbed areas may increase turbidity and reduce water quality in receiving waters. Wildlife habitat may also be adversely affected. Furthermore, digging vegetation and activities that result in the placement of fill in a wetland may be regulated under Section 404 of the Clean Water Act and may require a permit from the U.S. Army Corps of Engineers and/or appropriate state environmental agencies. Appropriate agencies should be consulted prior to collection.

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[1] Personal Communication. (1994). John Munro, Munro Ecological Services, Inc., Harleysville, PA.

Unlimited access to wetland plant material is not advisable, but the following measures can be taken to minimize impacts of plant material collection.

Salvage plant material from wetlands to be destroyed

If the wetland restoration project is being conducted as mitigation for impacts on wetlands, the wetland plant material that would otherwise be lost can be salvaged for use in the wetland restoration project. Planning is required to coordinate plant and topsoil salvage operations in the donor wetland with planting requirements in the recipient wetland. Minimization of storage time during hot or dry periods is critical for maintaining viability of the material.

Collect seeds rather than established vegetation whenever feasible

Seed collection has temporary impacts on plant populations. Because less than 100 percent of the seeds of a population are likely to be collected, impacts of seed collection on regeneration will have minimal impacts for more than a growing season. Trampling of plants and soil compaction should be avoided by not concentrating activities in a small area.

Collect plant material from areas with abundant supplies

Many wetland plant species, particularly herbaceous species, are capable of rapid growth and reinvasion of cleared areas. Limited collection of plant material can be made from areas where ample material remains to replace the collected plants. Small collections made in several well spaced areas have less impact than the removal of a large amount of material from one place.

Limit number of collection trips to the same area

Large quantities of material are often required for wetland restoration projects, and pressure can be great on plant populations in donor wetlands. Donor plant populations will be decimated if care is not taken to limit the collection of plant material in an area that is not allowed to fully recover before additional collections are made. Moreover, it is advisable to maximize the genetic diversity of plant material by collecting from separate populations of the same species.

Leave the donor wetland looking undisturbed

Disturbance to the donor wetland vegetation should be minimized. Unless the donor wetland is being salvaged prior to destruction, there should be little evidence that plant material has been collected from a wetland. A maximum amount of plant material that can be collected from a site should be set. For example, plant collection should result in no more than a 10-percent reduction in cover of the target species. If a sedge has 100-percent cover in a donor wetland, at least 90-percent cover of the sedge should remain after collection. Or, if a shrub has 50-percent cover, 45 percent of the shrub cover should remain after collection. Regardless of the amount of vegetation collected, remaining vegetation should be intact and erect.

Physical disturbance should also be minimized. Water quality should not be impacted. Drainage patterns should not be altered by tracks or digging. Accessing a donor area by boat may help minimize disturbances in access areas.

Contract Specifications for Collecting Plant Material

Many of the advantages of using plant material collected from native wetlands also lead to problems in actually attaining what was planned (Table 1). Much of the work in finding donor wetland sites, collecting the material, and delivering the material in sound condition is often contracted, and this is a point where quality control can be lost. Control over the source of materials can be specified, for example, but it is difficult to confirm that the plant material was actually collected from the desired source. The best means to ensure that the correct plant material was collected and delivered as planned is through carefully designed contract specifications.

As with standard contract specifications for commercial plant material, contract specifications for plant material collected from native sources must stipulate the species, size, number, and health or viability of the plants or seeds that are delivered to the site. It is important that someone familiar with plant material (i.e., a horticulturalist or forester) be specified that will be on site to accept or reject the material. This person should be able to identify whether the plant material meets the contract specifications. If the plant material does not meet the specifications, the plant material expert should be allowed flexibility to accept appropriate species substitutions or other departures from the contract.

Flexibility is a particularly important feature in contract specifications for native plant materials because of relative lack of control over donor site conditions. It must be recognized, for example, that adequate quantities of specific species may not always be available as contracted for reasons beyond the control of the contractor. For example, if the desired plant species are not accessible as planned due to high water, alternate species that have similar ecological values and tolerance of site conditions may be acceptable. Alternatively, planting may be delayed until the desired material is available or other sources are located.

Departures from standard specifications for native plant material sources are primarily in contract specifications of where and how the material is collected as well as how the materials for plant-soil transfers are handled. Contract specifications for native plant materials may include one or more of the following:

a. Specific location of the donor wetland.

b. Type of donor wetland (e.g., intertidal, brackish marsh).

c. Ecoregion or maximum distance from project site (e.g., within 80 km (50 miles) latitude and 160 km (100 miles) longitude).

d. Number of parent individuals for seeds or cuttings (i.e., to increase genetic variation).

e. Dormancy state when collected.

f. Size range of stem or rhizome cuttings.

g. Volume of wetland plant-soil material.

h. Minimum amounts of plant-soil material dewatering.

i. Maximum storage time for plant-soil material.

j. Matching of hydrological conditions of wetland project site with wetland plant-soil donor site.

k. Segregation of plant-soil material from different hydrological conditions.

l. Upland storage areas of plant-soil material.

m. Methods for collection of seedbank samples for germination studies.

n. Results of seedbank germination studies for nuisance species.

o. Minimization of disturbance to donor wetlands.

Because many of these specifications are difficult to enforce, it may be advisable to plan to have company representatives meet contractors at the donor sites to verify collection conditions.

Examples of Uses of Native Plant Materials: Case Studies

The remainder of this report is devoted to three wetland restoration and creation case studies. The studies are mitigation projects located in different parts of the country. Each study is intended to illustrate a technique for establishing wetland vegetation using native plant material sources. Included in each case study is a description of how revegetation of the project was planned and implemented.

Case Study #1 was a wetland creation project in South Carolina along the shoreline of L-Lake, which was a cooling pond for a nuclear production facility. The objective of this project was to establish a diverse biological community that would be able to withstand the stress of elevated water temperatures. Revegetation of L-Lake was accomplished by transplanting vegetation from a nearby cooling pond.

Case Study #2 was a marsh creation project in South Florida that mitigated for impacts to on-site wetlands. Revegetation of this site was accomplished by spreading mulch from a wetland to be destroyed over the created wetland ground surface.

Case Study #3 is a restoration project for an endemic wet prairie community in the Willamette Valley, Oregon. A variety of techniques, including whole-tree transplants, seeding, and sod mat transfers, was used to restore components of this valuable community type.

2 Case Study #1: L-Lake, Savannah River Plant, South Carolina[1]

Background

The Savannah River Site (SRS) is a nuclear production facility operated by the Department of Energy (DOE) in order to produce weapons-grade plutonium and tritium for defense purposes. This 780-sq-km facility, located in South Carolina along the Savannah River (Figure 1), has five production reactors which were constructed in the mid 1950's. The Savannah River provides a source of secondary cooling water for these reactors and until recently also received thermal discharge (Sharitz et al. 1974, Gibbons and Sharitz 1981). One of the five reactors, L-Reactor, discharged its thermal effluents directly into a small blackwater stream, Steel Creek, between 1953 and 1968 (Figure 1). Thermal discharges (50 to 90 °C) increased stage and discharge from natural levels of 0.3 cu m s^{-1} to flows as high as 24 cu m s^{-1}. L-Reactor was placed on standby status in 1968, and Steel Creek was allowed to return to relatively natural flows. In 1980 a decision to restart L-Reactor was made based on the need of plutonium for defense purposes. The National Environmental Protection Act (NEPA) required DOE to prepare an environmental impact statement (EIS). The EIS proposed options for thermal discharges ranging from direct discharge to mitigation of thermal discharges by cooling towers, cooling lakes, or various combinations. The mitigation alternative selected was the construction of L-Lake, a once-through cooling reservoir. L-Lake was constructed by placing a 1,200-m-long, 27-m-high earthen dam across the Steel Creek corridor. The resulting reservoir is 7,000 m long and 1,200 m wide and covers approximately 405 ha (Figure 2). Construction of the lake began in autumn 1984; the lake was filled in October 1985, with L-Reactor coming on-line at that time.

The permitting process that led to the construction of L-Lake is a complex story that triggered several mitigation processes (McCort et al. 1986, Wein

[1] Written by Dr. Gary Wein, Savannah River Laboratory, Aiken, SC, and Dr. Gary Pierce, Southern Tier Environmental Consultants, Inc., Portville, NY.

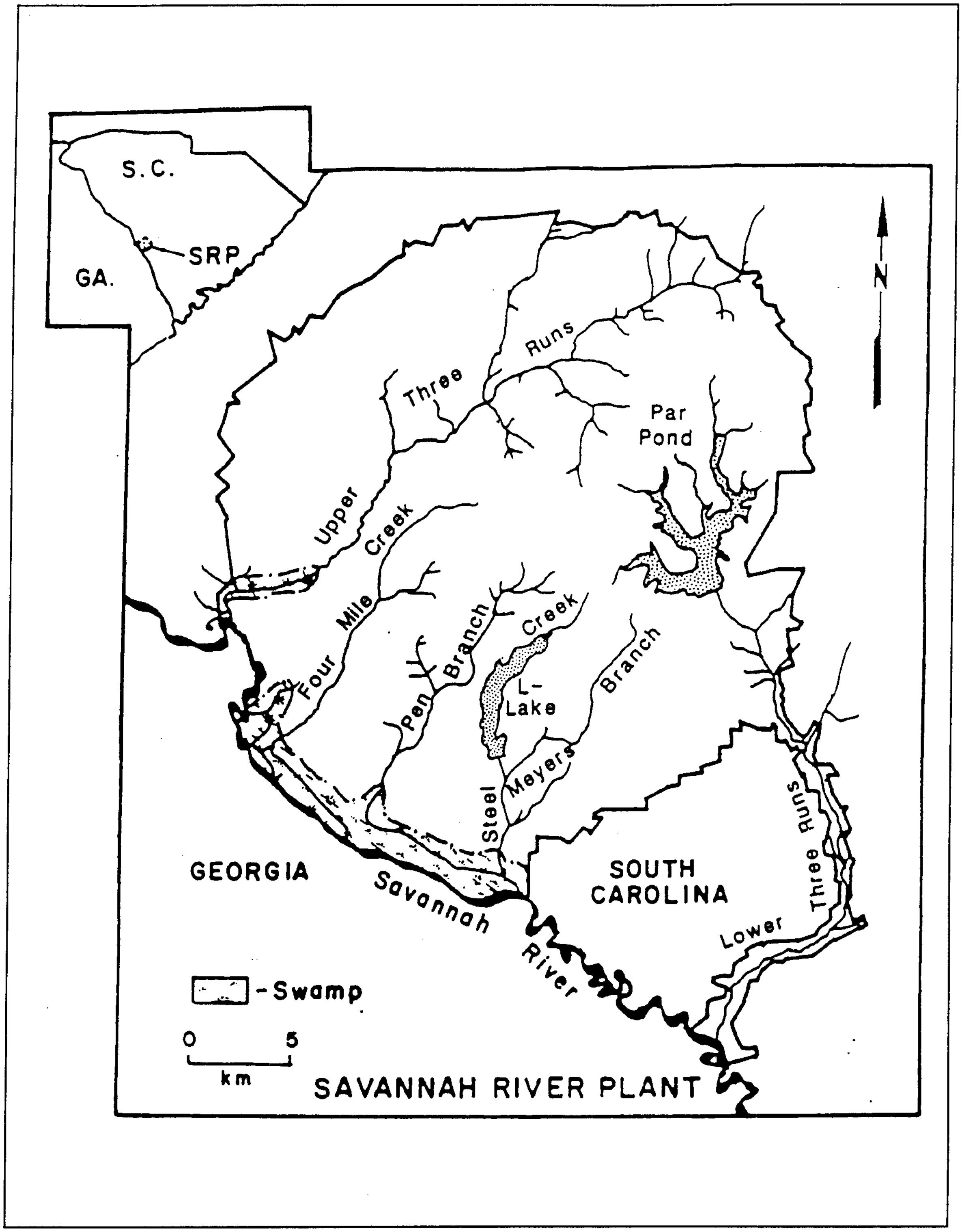


Figure 1. Site map for L-Lake wetland/littoral vegetation establishment

and McCort 1988). A National Pollution Discharge Elimination System (NPDES) permit required that effluent limitations be imposed which "assure the protection and propagation of a balanced, indigenous population of

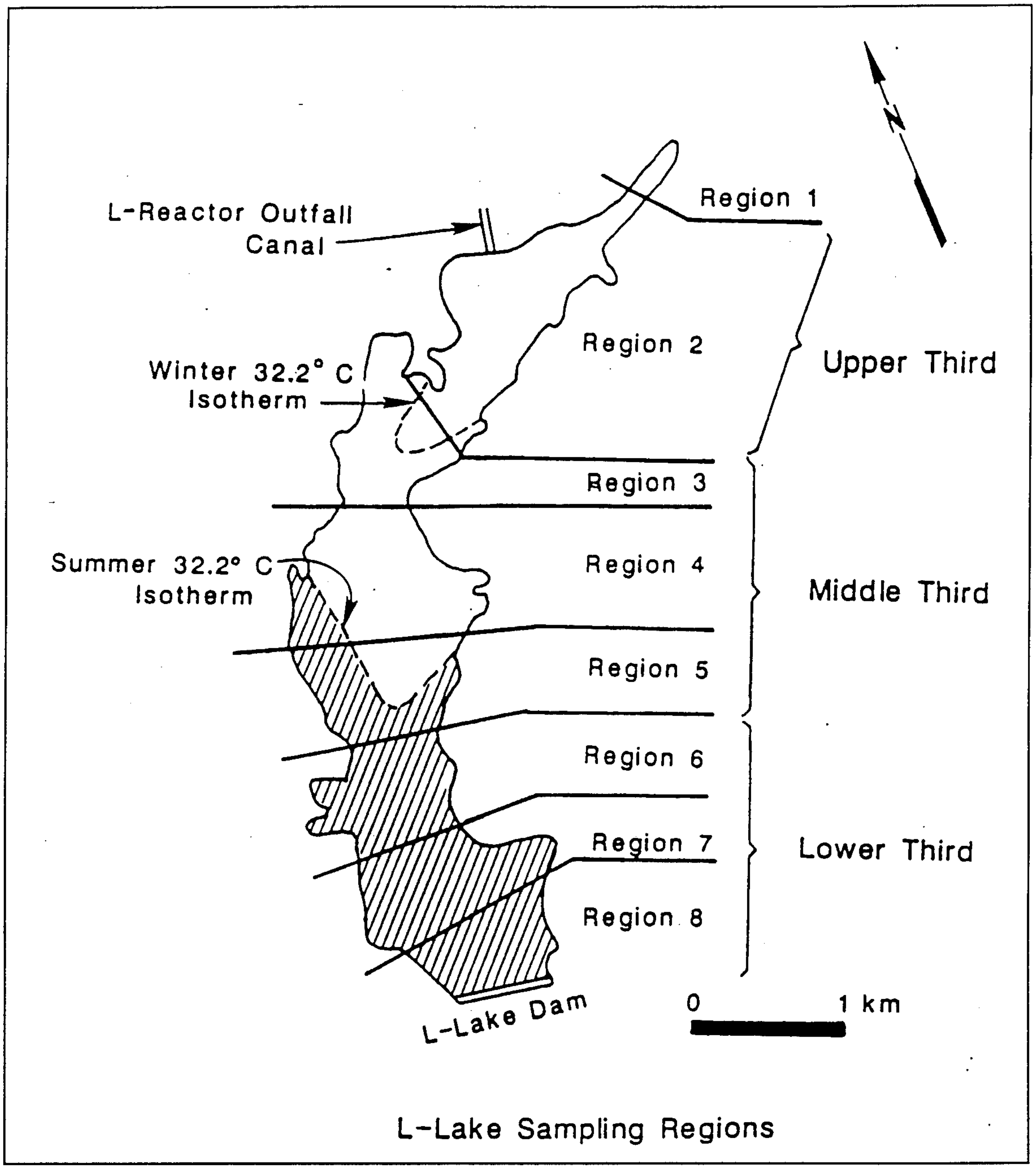


Figure 2. L-Lake biological sampling regions. Wetland vegetation is to be established within continuous plantings in the lower third. Wetland vegetation will be planted within research areas located in the upper and middle third of L-Lake. Hatching denotes the area for the development of a balanced biological community (BBC)

shellfish, fish, and wildlife in and on that body of water" when thermal discharges could cause a significant environmental impact. L-Lake was designed so that water temperature at the dam outfall would not exceed 32.2 °C during reactor operation so that the lake could support a "balanced biological community" (BBC) in the southern 33 to 50 percent of the lake. A BBC must have the following characteristics:

a. The lake must not be dominated by thermally tolerant species.

b. The lake must support biotic diversity and productivity similar to other lakes in the region.

c. The lake biota must include representatives of all trophic levels typical of lakes in the region.

d. The biotic communities of the lake must be self maintaining and not require restocking.

DOE made efforts to enhance physical structures that could provide suitable habitat for fish and wildlife. These included construction of artificial reefs, coves, small bays, and retaining forested areas within the lake. DOE also requested that the University of Georgia's Savannah River Ecology Laboratory establish wetland/littoral vegetation along the shoreline of L-Lake.

Wetland vegetation will develop naturally on the shoreline of the cooling reservoir. Par Pond, a recirculating reservoir, constructed on the SRS in 1958, had a very well developed wetland/littoral vegetation that established naturally. (In 1990 this wetland system was disturbed as the pool level was dropped approximately 6 m due to weakened dam conditions.) Planting wetland/littoral vegetation in L-Lake was necessary, however, because the NPDES permit did not allow sufficient time for natural establishment of wetland vegetation. The DOE felt that the attempted establishment of wetland/littoral vegetation would provide a good faith effort towards the establishment of a BBC. In addition, and perhaps more importantly, the establishment of vegetation would accelerate successional processes and provide structural habitat for the developing aquatic community and wildlife as well as shoreline stabilization.

The successful establishment of wetland vegetation along the shores of L-Lake was accomplished through planning, proper construction of the shoreline, and hiring a professional wetland restoration ecologist. Documenting plant establishment success invites a holistic approach. A synopsis is provided in this report of the planning effort and transplanting techniques.

Planning

Planning was essential to this project. Before vegetation was established, a panel of wetland scientists considered various management options. The panel visited the L-Lake construction site and Par Pond (a naturally vegetated reservoir), reviewed relevant project documents, and provided objectives and management recommendations (Whigham et al. 1985).

The panel recommended that "the primary objective of any planting effort in L-Lake be to establish and maintain biotic and abiotic resources needed to support a BBC in the coolest third of the lake" (Whigham et al. 1985). An essential element to establishing the BBC was the planting of wetland/littoral vegetation around L-Lake typical of regional lakes. The vegetation should have the ability to spread rapidly, provide fish and wildlife value, stabilize the shoreline, and contain plant species that are thermally tolerant but not characteristic of thermally polluted systems. The panel also recommended that nearby Par Pond (Figure 1) would provide a reference system after which the established community in L-Lake could be modelled.

Par Pond is an example of a cooling reservoir that supports a BBC (Wetzel 1975) and contains elements of a typical southeastern lacustrine system (Cowardin et al. 1979). Par Pond is surrounded by distinct bands or zones of vegetation that correlate with water depth (Figure 3) (Grace and Tilly 1976, Grace 1984). These zones include:

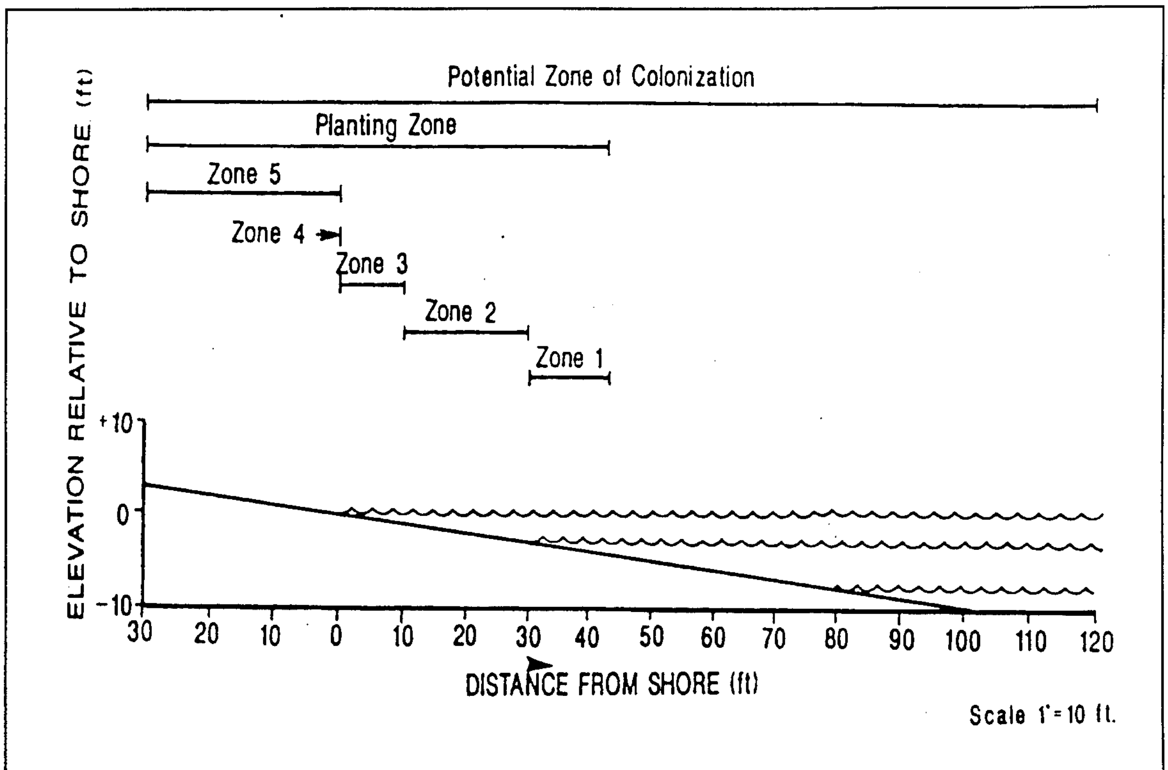


Figure 3. Planting zones. Horizontal distance varies with shoreline topography

a. Zone 1. Submersed aquatic plants.

b. Zone 2. Floating leaved plants.

c. Zone 3. Emergent persistent and nonpersistent herbaceous plants.

d. *Zone 4.* Narrow zone at the water/land interface dominated by Zone 3 plant species.

e. *Zone 5.* Shrub and tree zone.

The panel recommended that Par Pond provide a model for the establishment of wetland/littoral vegetation within L-Lake and that the plant species found within the five zones be transplanted from Par Pond to L-Lake. Par Pond would be an ideal donor site for plant species because it has a plant community representative of regional lakes, has genotypes selected for elevated thermal conditions and would logistically provide a convenient source for the collection of plant material. The nearby location of Par Pond would reduce cost and enhance survivability of transferred material by reducing handling time.

There were three management options recommended by Whigham et al. (1985): option 1, no action; option 2, block planting; and option 3, continuous planting. The no-action option would have led to eventual establishment of vegetation, but this process would have been very slow due to basin scouring prior to filling reducing the natural seed bank, low nutrient conditions, and high wave energy. Also this option would not meet DOE's stated goal of a good faith effort towards a BBC. This option was not recommended by the panel. Both options 2 and 3 called for the planting of commercial or transplanted material along the shore of L-Lake by using cores or spragging vegetative material (rootstocks or rhizomes) into the five zones shown in Figure 3. Option 2 called for the planting of 15-m by 23-m blocks at 183-m intervals along the shoreline of the lower third of the lake. Option 3 called for the continuous planting along the shoreline.

As a result of restricted access to portions of the shoreline, the decision was made to go with the panel's option 3, continuous planting where shoreline was available with slopes greater than 10H:1V. The planting requirements that were identified are listed in Table 2. Four more tasks were identified in addition to planting the 6.2 ha:

Table 2
Required Plantings in L-Lake

Zone	Depth, m	Area Range	Number of Plants
1-Submersed	-1 to -1.2	2.3 ha	15,518
2-Floating leaved	-0.3 to -0.6	2.5 ha	16,879
3-Emergent	0 to -0.3	2.6 ha	70,785
4-Strand	0	5,574 m	12,193
5-Tree/Shrub	0 to 0.6	6.2 ha	6,665

a. Establishment of a pilot plot in 1986 in order to identify planting methods and logistical problems (project cost $5,000).

b. Planting experimental plots for controlled measurements by SREL staff.

c. Planting an additional 4,500 m of shoreline to one to three rows of emergents at 1- to 3-m intervals (estimated average two rows at 2-m interval requiring approximately 1.1 ha and 7,500 plants.

d. Constructing two breakwater structures and planting behind them.

With all amendments, an estimated 250,000 plants were planted at an average cost of $0.65 each.

Site Assessment: Physical Characteristics

The establishment of wetland vegetation along the shores of L-Lake was accomplished primarily by transplanting individuals from Par pond. However, successful transplanting required information on the physical characteristics of the site relevant to the plants' survival and placement.

Geography

L-Lake was designed to be a cooling reservoir, not a wetland system. Because the lake was constructed in a stream valley, the actual configuration of the lake is long and narrow with significant fetch in some portions of the lake. Because DOE was required to establish a BBC in the lake, some consideration was given to providing refugia for aquatic organisms in the form of coves and shallow areas along the shoreline. The natural topography of the surrounding landscape provided additional shoreline topography. While DOE had intended for there to be a gradually sloping shoreline, the dam contractor required additional fill in the last month of construction (McCort et al. 1986). This fill material was borrowed from the graded shorelines and resulted in 3- to 4-m dropoffs along portions of the shore.

Hydrologic regime and wave energy

Water depth, hydroperiod, and wave energy are important considerations in wetland plant establishment. Although mature plants of a particular species exhibit adaptations to specific water depths, seeds and immature individuals may require shallower water or saturated soil to become established. The range and timing of water depths can promote or discourage growth or even result in the death of plants. High water during periods of high metabolic activity can kill a plant; whereas, many species can tolerate periods of high water during dormancy.

Wave energy can influence species composition and survival. Scouring of plants and substrate will occur in high energy zones. These areas will have a poor nutrient regime resulting from the scouring of organic matter and, in addition, will not develop a rich seed bank. Cove habitats, in contrast, would be expected to develop a rich seed bank and substrate rich in organic matter and nutrients.

Water depth and hydroperiod in L-Lake are controlled, with a pool level elevation to be maintained at 190 ft as referenced to the National Geodetic Vertical Datum (NGVD). Water level fluctuations are limited to 1 metric by L-Lakes's NPDES permit requirements. This is unlike many other reservoirs which may experience water level fluctuations many times greater. Water levels did fluctuate greatly during planting and made the identification of zones 1 through 4 difficult. Fluctuations were due to reactor schedules and were not under the control of SREL. As a result, some plants were inundated soon after planting.

Substrate

The SRS is located on the coastal plain of South Carolina, and the soils are derived from tertiary marine deposits. The soils that developed from these sandy parent materials are primarily soils of the Troup-Lucy Association (SCS 1990). These soils are well drained with a loamy subsoil and sandy surface. These soils have less than 1 percent organic matter and are infertile. All soil surfaces except those with standing trees were scraped to remove organic matter, the resulting substrate being reduced to the sandy parent material.

All soils were basically the same through the lake with the exception of clay areas located at the southern end of the lake. These clay areas possess a hardpan and provide very hard substrates unsuitable for anchoring plant material. In general, these areas were not planted, and where some effort was made to plant, success was generally poor.

Nutrient conditions

Fertilizing was necessary because most of the planting substrate consisted of sand low in fertility. Soils at L-Lake were not analyzed for nutrients. However, a long history of research on the site, particularly in abandoned agricultural systems suggested that the soils were not nutrient rich. Each individual plant was planted with one or two 10-g tablets of timed-release Agriform fertilizer (20-10-5). Using this type of localized application of fertilizer avoided the eutrophication of the lake system that might have resulted in undesirable algal blooms. The fertilizer also stayed in place without being lost in the water column.

Contractor Logistics

Labor

Importing experienced labor to the project site would present excessive costs associated with transportation and per diem. Hiring labor in the Aiken area would reduce these costs but could be a cumbersome process. As a solution, a temporary employment agency that specialized in supplying day labor was used. For a modest fee, the agency supplied laborers, kept the employees on their payroll, paid all required state and federal taxes and fees, and provided liability insurance. Laborers could be added or eliminated with only 1 or 2 days notice, and in addition, unacceptable employees could be readily discharged.

Day laborers hired through a local temporary agency were trained to recognize plant species, to collect, and to plant. A local landscaping firm was used initially to supply experienced supervisors and a truck to transport plants. This was an expensive source of skilled workers who proved no more capable than less expensive labor supplied through the temporary agency. Essentially all of the local staff expressed extreme fear of snakes in the water. The crew was also unable to work effectively in the cold. Once the crew was trained and acclimated to the field conditions, most of the workers became willing and efficient collectors and planters. Ultimately, after several unsuccessful efforts, the temporary service was able to find a skilled and enthusiastic supervisor who quickly gained knowledge of the technical aspects of the planting.

Transportation

There were two transportation problems to be solved: transport to the site and movement of plant material. Laborers car-pooled to the site. Plants were transported either in a cargo van or in an open pick-up truck.

The geography of the Savannah River Plant presented an additional limitation to efficient work. Planting and collecting locations were often accessible only by boat. Transporting workers to planting and collecting sites by boat was extremely inefficient. Plants collected in Par Pond were transported more than 1/2 hr to L-Lake.

Supplies

Although the act of collecting and planting wetland plants did not require a large quantity of supplies and equipment, having appropriate materials on hand was often troublesome. Plant collectors required the following:

a. Potato hook, garden cultivator, or shovel to collect plants.

b. Pair of anvil pruners to divide plants into planting units.

c. Galvanized wash tub or silage tub to store plants.

d. Tether to keep the tub from floating away.

e. Hip boots or barn-style boots.

f. Rainsuit.

Each planter had the following:

a. Tile spade or planting bar.

b. Tree planting bag to transport plants.

c. Canvas carpenter's apron to carry fertilizer.

d. Pair of waders or barn-style rubber boots.

e. Rainsuit.

Planters placed between 500 and 1,000 plants per day and required an equal number of 10-g fertilizer tablets. Transporting the plants required a quantity of heavy duty plastic bags and galvanized tubs.

Planting submerged aquatics in weighted plastic bags called for the following:

a. Bolts of cheesecloth.

b. Scissors.

c. 10 g 20-10-5 Agriform fertilizer tablets.

d. Pebbles 1 to 2 cm in diameter.

e. Stapler and staples.

f. Supply of plants floated in galvanized tubs.

g. Additional galvanized tubs of water to hold planting units.

Construction of the breakwater called for the following:

a. Skill saw.

b. Randomly sized rough cut hardwood approximately 2.5 by 5 cm and 3 to 4.5 m in length.

c. Sledge hammer for driving the stakes.

Plants were transported to and from the lake in a pick-up truck or cargo van. Plants were transported in either plastic lawn bags or in wash tubs. Plants in wash tubs were also covered with a tarp in order to avoid wind burn. Transportation of personnel to collecting or planting sites by truck or van was often possible. Much of the lake shores was not accessible by road, and boats were used to reach more remote areas. On each lake, one 12-ft fiberglass Jon boat with a 15-hp outboard motor provided access to these more remote locations.

Planting

The primary method used to establish wetland vegetation in L-Lake was planting individual plants, rhizomes, and seeds. All species were planted between January and August 1987. The winter and spring plantings occurred during the optimum planting window for all species.

Species selection

A list of species that could successfully be established in L-Lake was compiled from lists of species in Par Pond and those in wetland establishments elsewhere. Recommended species (Whigham et al. 1985) had the following characteristics:

a. Had a high probability of quickly becoming established and spreading vegetatively.

b. Had a high value for wildlife and fish.

c. Were locally available or could be easily obtained from commercial sources.

d. Were components of littoral/wetland vegetation in the region.

e. Had the potential to tolerate elevated water temperatures.

f. Had a high potential for stabilizing the shoreline of L-Lake.

g. Had potential for trapping sediments and organic matter that were necessary for developing a complex food web and supporting organisms in higher trophic levels.

Species planted in L-Lake are listed in Table 3. Since most of these species were from Par Pond, a thermally impacted reservoir, they were expected to tolerate elevated water temperatures. Criteria for determining which species might be planted from Par Pond were indicated by Whigham et al. (1985). In addition, the following criteria were developed as the planting progressed:

a. Species considered to be troublesome weeds were not transplanted.

b. Annuals were not transplanted.

c. Abundant species on Par Pond were favored over less common species.

d. If a plant on Par Pond could be collected, it generally was considered a candidate for transplanting.

e. In general, species with basal meristems and/or underground rhizomes were favored. This meant that monocots were generally favored over dicots.

f. Plants that could be collected with less labor were favored over those that were more difficult to collect.

g. As many species as could be located were transplanted, even if only a few tens of plants were transplanted.

h. It was not considered necessary to determine the identity of a species in order to transplant it. If it appeared that it could be transplanted with probable success and was not a problem weed, it was transplanted—at least in small quantities. The plants were later identified when in flower or fruit on L-Lake.

i. Personal bias of the planting contractor favored graminoid species.

Although some of these criteria may seem casual, there was no precedent for transplanting most of the species growing on Par Pond. Also, SREL gave the planting contractor leeway to test various species, and the contractor accepted that as a challenge to maximize the success and diversity of the BBC that was being constructed.

Table 3 lists many of the species that were planted, but it is not a comprehensive list. Other species were planted in small numbers and never identified or recorded. In addition, there were often miscellaneous species mixed

Table 3
Species Targeted for Each Zone and the Approximate Number of Individuals Planted in L-Lake

Species	Approximate Quantity	Initial Success
Submersed Zone - 1		
Eleocharis acicularis	<2,000	
Najas gracillima	<100	0/0
Potamogeton vaseyi	<100	0/0
Potamogeton pulcher	<1,000	0/0
Vallisneria americana	>2,000	3/3
Floating-Leaved Zone - 2		
Brasenia schreberi	<1,000	1/0
Nelumbo lutea	<1,000	2/3
Nymphaea odorata	>2,000	2/1
Nymphoides aquatica	<100	?/?
Emergent Zone - 3 and 4		
Axonopus sp.	3.73 kg[1]	3/10
Bacopa carolinia	>2,000	1/1
Carex glaucescens	<100	?/?
Carex comosa	>2,000	1/1
Cladium mariscoides	<100	?/?
Decodon verticillatus	<1,000	2/1
Dulichium arundinaceum	<100	?/?
Echinochloa crusgalli	9.3 kg[1]	3/0
Echinodorus cordifolius	<100	2/3
Eleocharis equisetoides	<1,000	1/1
Eleocharis quadrangulata	>2,000	3/3
Erianthus giganteus	<100	?/?
Glyceria striata	<100	1/1
Hydrochloa caroliniensis	<1,000	3/2
Hydrocotyle umbellata	<100	2/3

(Continued)

[1] Planted in Zone 4.
Note: Initial success of the plantings is indicated with a ratio: numerator indicates survival; denominator indicates rate of spread on a 0 to 3 scale. 0 indicates no survival or growth, 3 indicates high survival or spread (>75%), NA denotes no data.

Table 3 (Concluded)

Species	Approximate Quantity	Initial Success
Emergent Zone - 3 and 4 (Continued)		
Juncus diffusisimus	<100	3/1
Juncus effusus	>2,000	3/1
Juncus acuminatus	<100	3/1
Juncus brachycarpus	<100	3/1
Leersia hexandra	>2,000	3/2
Leersia lenticularis	<1,000	3/2
Leerisa oryzoides	<1,000	3/2
Leersia hexandra	<1,000	3/1
Lycopus rubellus	<1,000	2/1
Mikania scandens	<100	0/0
Oenothera sp.	<100	?/?
Panicum hemitomon	>2,000	3/3
Panicum virgatum	10 lb[1]	3/0
Polygonum cf amphibium	<2,000	3/3
Pontederia cordata	<1,000	3/2
Sacciolepis striata	<1,000	3/3
Sagittaria latifolia	2,000	1/?
Scirpus cyperinus	>2,000	2/1
Sparganium americanum	<100	1/1
Typha domingensis	<1,000	2/3
Typha latifolia	>2,000	3/3
Shrub and Tree Zone - 5		
Acer rubrum	>2,000	3/NA
Alnus serrulata	>500	1/NA
Cephalanthus occidentalis	>2,000	3/NA
Nyssa sylvatica	>2,000	2/NA
Taxodium distichum	>2,000	3/NA
Salix nigra	>2,000	3/NA

with the collections that were included by accident. These "accidental" species were as propagules in attached sediments. Efforts to clean transported plants were limited to removing minimal sediments and weedy plant species

(*Myriophyllum* and *Ceratophyllum*). No effort was made to eliminate these plants; to the contrary, the laborers were encouraged to include whatever they found.

Plant acquisition

All plants were collected by hand. Almost all plants were collected on Par Pond, but some were obtained from seepage areas at the base of the L-Lake dam (notably *Leersia hexandra*). A few others were collected in a small floodplain bottom just northeast of L-Lake (*Sparganium americanum* and *Cladium jamacense*), and some *(Cephalanthus occidentalis)* came from a Carolina bay on the plant site. *Sagittaria latifolia* (2,000 plants as dormant tubers) came from Kesters Wildlife Nursery in Omro, Wisconsin. Approximately 1,300 (60 - 120 cm) *Acer rubrum*, *Nyssa sylvatica*, and *Taxodium distichum* bare root seedlings originated at Hess Nursery in McMinville, Tennessee.

Collecting involved harvesting the plants either by pulling them by hand or with a long-handled garden cultivator. A few plants were dug with shovels. The soil was washed off the roots and rhizomes to make the plants lighter to carry. If rhizomes were long or the plants were in clumps, they were divided into planting units at the collecting location by breaking them apart or cutting them with an anvil pruning shear. The plants were placed in galvanized tubs, plastic bags, or in the bottom of the boat as they were collected.

Plant storage and transportation

Plants were transported under cover or submerged in water in order to prevent desiccation or overheating. In general, when the weather was cool this was accomplished by using plastic bags. This was effective and inexpensive. After the weather warmed in the spring and temperatures were above 15 °C, plastic bags of plants in the sun became quite hot and care was required to keep the plants in the shade or in open tubs of water. Plants were transported covered either in a van or under a tarp in the back of a pick-up truck.

The most effective method of preserving plant viability between collection and planting is to shorten that time as much as possible. During this project, the goal was to plant all plants within 48 hr of collection. To accomplish this, two crews were used, a collecting crew and a planting crew. At the end of each day, the collecting crew would bring from Par Pond that day's collection to be planted the next day. If there were too few plants being supplied by the collecting crew, some of the planting crew would assist with collecting for a few days. The 48-hr goal was frequently not met, but it was rare that plants were in storage for more than 3 days.

Plants were stored at L-Lake before planting. This usually involved submerging the plants in water overnight. During much of the planting, plants were stored in an ephemeral pond about 200 m from L-Lake. This pond was in a dense pine forest and was completely shaded. When the pond was not available either before it was discovered or after it had drawn down, plants were stored in tubs of water on the edge of the lake or in plastic bags in the water and secured to the bottom by heavy rocks. During thunderstorms the bags sometimes were dislodged, but the plants were usually found floating along the edge of the lake. Submerged aquatics and floating-leaved aquatics were generally stored for less than 24 hr, often collected in the morning and planted that afternoon or the next day.

Planting Techniques

General planting technique

In general, planting units were a plant base or rhizome piece with at least one bud. Sometimes as many as three plant bases were accumulated for one planting unit. The planting unit was always small enough to fit in a hole opened by a "tree planting bar" or by a "tile spade." This hole was approximately 10 cm by 5 cm at the top and 20-cm deep.

Plants (except part of the *Vallesneria americana* discussed below) were planted by hand by placing them in a slit made in the substrate with a tile spade or planting bar. The technique was the same whether planting above or below the water level. The planters had a supply of plants in a tree planting bag strapped to their waists and a supply of Agriform tablets in a cloth carpenter's nail apron. The planter made a slit in the soil and when under water left the shovel in the slit while getting a fertilizer tablet and planting unit in one hand. While keeping the slit open, the plant and fertilizer were placed in the hole, and the soil was packed around the plant. If this was done with care, even the most buoyant plants stayed in the hole when planted under water. Generally, efforts to keep the plants in the planting hole with wire hooks or stone weights were inferior to jamming a buoyant plant tightly in the hole and packing the soil around it. Whenever there was an apparent up/down orientation to a plant, the root/shoot relationship was maintained during planting. This was not always as simple as "green end up."

Submersed

Initial plans included six species for planting in the submersed aquatic zone which was defined as a 1- to 1.3-m depth of water. Of those, *Ceratophyllum demersum* and *Myriophyllum spicatum* were not planted because they are weedy. *Najas gracillima*, *Potamogeton vaseyi*, *P. pulcher*, and *Eleocharis acicularis* were planted only in modest quantities. *Vallesneria americana* was planted in large quantities largely because on Par Pond it was readily available; it grew in high wave energy environments which were anticipated on L-Lake, and it demonstrated high success. Success had been demonstrated when it was planted with *Potamogetons* and *Najas* during the 1986 pilot planting.

Originally, it was intended to plant this zone by physically planting each plant just as the emergents were planted. Fear of disease from *Naeglaria fowleri* infection made this impossible. This amoeba-like organism, typical of thermally charged waters, can travel through the nose, mouth, or open sores. Consequently, most of the *Vallesneria* planted on the lake was planted by dropping small weighted bags each containing three *Vallesneria* rosettes, a fertilizer tablet, and a couple of pieces of gravel into water 0.6- to 1.3-m deep. These bags were constructed of cheese cloth and stapled closed. Cheese cloth was chosen because it is readily biodegradable. It was difficult initially to see these planting units on the bottom, and it was not possible to judge how effective this technique was. After *Vallesneria americana* was transplanted, it lost its long leaves and developed a small inconspicuous rosette which, during the first couple of years, gradually elongated until its more familiar form developed. It is important to recognize this behavior in determining its establishment success.

Additional *Vallesneria* were planted on exposed points of land in zone 2. Here the plants were planted at 0.6-m intervals. The remaining submerged aquatics were planted in small quantities, both by weighted bags and by direct planting in zone 2. The *Potomogeton* and the *Najas* appeared not to survive at all. Where they were planted in zone 2, no plants were evident on later visits.

Floating leaved

Floating-leaved species present in Par Pond included *Brasenia schreberi*, *Nelumbo lutea*, *Nymphaea odorata*, and *Nymphoides aquatica*. All four of these species were collected from Par Pond. They were stored in water and transported to L-Lake where they were transplanted by hand. Planting occurred in water from 0.3- to 0.75-m deep, shallower than that specified for zone 2 because the presence of *Naeglaria fowleri* made planting in deeper water potentially hazardous.

Nelumbo lutea has a deep horizontal rhizome and was difficult to harvest. It produces a swollen, banana-shaped storage tuber on terminal portions of the rhizomes. Preliminary planting experiments in August 1986 showed poor success with other portions of the rhizome. Commercial growers of *Nelumbo* suggested that the "bananas" might be successful. These were extraordinarily difficult to collect in most locations where the bananas grew as much as 45 cm below the surface of the substrate in water often 0.6 m or more deep. In one location on Par Pond where there was hard clay covered by only 7 to 10 cm of soft mineral soil in less than 18 in. of water, the ends of the bananas were exposed, and several dozen of the tubers were collected involving about 15 min of effort for each transplant. These tubers were planted on L-Lake at approximately 100-ft intervals. The tubers were readily planted by making a slit in the substrate with a tile spade and packing the disturbed soil around the tuber.

Nymphaea odorata was the primary species planted in the floating-leaved aquatic zone. Terminal meristems with a few leaves attached were harvested by hand in water 0.6 to 1.3 m, transported and stored in water, and planted on 1.3-m intervals. Attempts were made to anchor the plants with J-shaped wires and with rocks on top of the plant. These efforts were abandoned in favor of simply wedging the plants into the planting hole and packing soil around them. After planting, a review of the shore searching for floaters suggested that only 10 to 20 percent were lost. At the end of the first growing season, large numbers of *Nymphaea* were growing, but these were obviously being damaged by wave action.

Nymphoides and *Brasenia* were planted using the same techniques described for *Nymphaea* but appeared not to have survived. This was expected of the *Brasenia* since it was planted during the 1986 pilot project and appeared not to have survived there. *Nymphoides* was planted only in very small numbers and was probably not given a good trial.

Emergent Zone

Shoreline stabilization

Whigham et al. (1985) divided this zone into a shoreline stabilization zone, occurring at the water line, and a zone containing persistent and nonpersistent emergent vegetation. Thus, a portion of the zone was separated because of its function to stabilize the strandline. Grasses were the only vegetation type used in the shoreline stabilization zone.

The initial plans called for *Leersia oryzoides* to be planted in this zone. That species is actually quite rare on Par Pond, whereas *Leersia hexandra* is much more common. All of the *Leersia* species (Table 4) and *Hydrochloa carolinense* were transplanted as bare root transplants into this zone; *Sacciolepis striata*, *Panicum hemitomon*, and *Paspalum distichum* were transplanted into this zone differently from any other plants. The long rhizomes of these three plants were excavated as long, intact pieces ranging from 0.3- to 2-m long. A shallow trench was excavated parallel to the shore along the strand line. The trench was usually about 5 cm deep. The rhizomes were laid into the trench and fastened to the bottom with J-shaped wire hooks about 25-cm long. Finally, the shallow trench was refilled.

Wherever there was a bare area of soil, usually sand, just above the strand, grass seeds were planted. This was done during the summer when the lake level was slightly lower than earlier in the year in hopes that the seed and germinating grass might not be eroded. *Panicum virgatum*, *Axonopus* sp., and

and *Echinochloa crusgalli* seeds were obtained from a Georgia supplier. The soil was raked using a garden rake; lime, 10-10-10 fertilizer, and seed were spread on the raked surface by hand, and the soil was raked again and packed by walking it completely. Lime was spread sufficient to completely cover the soil surface, and seed and fertilizer were spread until only 1 or 2 mm separated each seed or fertilizer particle.

The monotypic grass plantings germinated readily and grew as a dense turf to about 15 cm in height before planting was finished and the site was vacated. On returning 60 days later, researchers were unable to find any of the grass plantings, presumably they were removed by waves.

Emergent plantings

Most species planted in this zone were transplanted as bare root transplants from Par Pond. Care was taken not to thoroughly clean the root systems in order to transfer some of the Par Pond seed bank with each core. Nevertheless, little if any soil was brought with most transplants. Cores extracted with a standard bulb planter were tried during the 1986 pilot planting. These were too heavy to transport efficiently, and no further soil cores were transplanted. On occasion, organic debris from the littoral zone of Par Pond was shoveled into the back of the truck, brought to L-Lake, and shoveled into the lake to be dispersed by waves and wind. In one instance, nearly 1 cu m was transferred in this manner. Care was always taken to clean collecting tubs and tools by washing them in L-Lake in an effort to enhance the seed bank.

Emergent species were planted on 0.6-m centers. Most of this zone was planted in the late winter and spring of 1987. But some additional plants were planted during the summer of 1987. Essentially all of this zone was planted with bare root transplants by standard means described above. A few important lessons, or special features of the plantings, are listed below:

a. Dormant rhizomes of cattails, *Typha latifolia* and *T. domingensis*, were collected by hand from Par Pond and transplanted into L-Lake during the late winter. Each transplant was carefully examined and had one or more living buds. A majority of these plants, perhaps 70 percent, never broke dormancy. Replanting took place in the spring using plants from the same areas of Par Pond. These plants had broken dormancy and most of them grew vigorously.

b. *Lycopus rubellus* was located when collecting cattails on Par Pond. Small, J-shaped, swollen pieces of stem, apparently overwintering structures, floated to the surface and were picked up on the water. These were typically from 7.5- to 15-cm long. They were planted with the J-portion placed in the substrate and locked in with a corresponding J-shaped wire.

c. *Pontederia cordata* was planted and grew prolifically, flowering and setting seed within 60 days of planting. Beavers and wild pigs had a particular affinity for the plants, and many of the stands were showing herbivory within 2 months of planting.

Shrub and Tree Zone

During January and February 1987, 45-cm cuttings of *Salix nigra*, *Cephalanthus occidentalis*, and *Alnus serrulata* were cut from branches of these species around Par Pond. They were transplanted simply by securely planting them vertically in the soil with approximately 25 cm below the soil and 20 cm above. These transplants were placed from the normal waterline to about 0.3 m elevation above the waterline. This technique was very successful, with approximately 80 to 95 percent of *Salix nigra* and *Cephalanthus occidentalis* sprouting. Alder were planted only at 33-m intervals on the shore in clusters of three cuttings. The alder was treated with rooting hormone before planting; some of these sprouted and rooted initially, but there was very limited growth from these plants by the end of the first growing season.

Bareroot seedlings of *Acer rubrum*, *Nyssa sylvatica*, and *Taxodium distichum* were obtained from a Tennessee commercial nursery. They were planted with a tree planting bar and a 10-g tablet of Agriform just as all other plants were planted. Trees were planted in February 1987 and were placed along the shoreline on 3-m centers, generally in the upper one-half of the tree/shrub zone. By the end of the summer of 1987, most of the trees were exhibiting vigorous growth.

Special Problems

A number of special problems associated with planting had to be solved. Such problems are often encountered on other projects, and their presence here was expected.

Water depth and planting zones

Whigham et al. (1985) recommended that the lake level not be allowed to fluctuate more than 15 cm during planting and establishment of vegetation. SREL staff indicated that this low level of fluctuation would, indeed, prevail. Within the first week of contract performance, the lake fluctuated nearly 60 cm. Subsequent experience showed that this pattern was typical and that raised or lowered levels of the reservoir often lasted 1 or 2 weeks.

The mean level of the reservoir was not accurately determined, and it was not possible to know the ordinary water level elevation or what it was supposed to be. Consequently, in order to perform the contract, the ordinary water level was arbitrarily established using as a basis about 1 month of daily casual observations and the apparent strand line on the lake shore. This level was established and a nail was driven at that level into a piling on a wooden dock. Subsequently, each day's planting zones were determined by the water level as measured from the nail.

Locating plants to collect

The target species were to be collected in quantity, and it was often difficult to find the plants. Par Pond is large and many portions are relatively inaccessible except by boat. In order to maximize collection efficiency, collections were desired at the most accessible points. Frequently, these areas lacked desired species, or the plants were unusually difficult to collect. Finding collection locales was a constant challenge for the collecting crew. What ultimately developed was the maxim that if plants were hard to collect, going to another spot often yielded plants that were much easier to collect. An example is that *Panicum hemitomon* was usually 5 to 10 times as easy to collect from organic soils as from sand.

Soil textures

In most parts of L-Lake, soils were either sandy loams or sands where planting was readily accomplished, and the substrate supported vegetation. In a few areas near the dam, where soil had been removed, remaining clay substrata were extremely hard, and a planting hole was chipped into the substrate. Transplants of all species placed into clay substrate were anchored using J-shaped hooks. Plants readily washed from the planting holes in clay substrata. In one other area, silt and sand had formed a "soupy" matrix into which planters readily sank to their waists. Planting here was from "duck boards," and plants were also easily removed by water action because the soil was eroded from around their roots. Most of the areas with these difficult soils are located on the west bank of the reservoir within 100 m of the dam.

Twigs and branches

On much of the west shore of the reservoir, hardwood stands were not cut before the reservoir was filled and the littoral zone was filled with standing dead trees that were dropping their branches into the water. It was difficult to plant among these branches, and their scouring action, as waves moved them back and forth in the water column, may account for some areas of more limited planting success on the western shore.

Wildlife

The planting and collecting crews occasionally encountered alligators and poisonous snakes. Whenever this happened, all work would stop for up to an hour until the workers settled back into a routine.

Purchasing plants

All of the commercially obtained plants and seeds grew well on the reservoir. A unique problem with *Sagittaria latifolia*, however, illustrated one reason that commercial stock may be inappropriate especially when moved several degrees of latitude. *Sagittaria* was purchased from Wisconsin and planted during February. Coots using the reservoir ate almost all of the tubers as they started growth. By the time the coots left the lake in the spring, they had decimated the imported population. A short time later the native *Sagittaria latifolia* that had populated the lake since it was filled broke dormancy and grew with no interference from herbivores.

Monitoring

In order to determine if the techniques used in establishing vegetation at L-Lake were successful, a total of 54 permanent transects were placed in planted (N = 32) and unplanted (N = 22) portions of the shoreline. These plots were first sampled in August 1987, immediately after the planting effort was complete. This sampling provided an estimation of contractor compliance as well as a baseline for future comparisons.

Whigham et al. (1985) recommended that transplant survival be assessed immediately after planting was completed, probably in August of the planting year. They recommended that the planted zones be assessed for percent survival and those zones not meeting a range of acceptable percent be replanted (Table 4). The recommended percent survival rates are based on a count of the number of surviving transplants.

Table 4
Recommended Acceptable Transplant Survival Percentages for L-Lake

Zone	Range of Acceptable Survival, %	Percent Cover	Percent Vegetated
1	10-20	1	5.2
2	30-40	no data	no data
3	50-70	22	67.9
4	50-70	no data	no data
5	30-50	59	100.0

In the 1987 sample, which was used to determine contractor compliance, only percent cover was measured within the sample plots. The recommended percent transplant survival and percent cover and number of plots vegetated are not directly comparable. However, if the percent vegetated plots are used as a comparison, the transplant goals were met for zones 3 and 5. Zone 1 was vegetated, but only marginally so. Data for zones 2 and 4 are not presented because in the analysis done by Kroeger (1990) these zones were combined with other zones; zone 2 with 3 and zone 4 with 5. The contractor was not asked to replant zone 1 because it was thought that wave action would substantially reduce survival.

A comparison of establishment in 1988 and 1989 with the baseline 1987 samples indicated that all planted zones showed significant establishment. A summary of these years follows.

Nine species of submersed and floating-leaved plants were transplanted into zones 1 and 2. Only two species, *Nelumbo lutea* and *Vallisneria americana*, appeared in the planted sample plots in subsequent years. In 1987, 95 percent of sample plots had no vegetation present but by 1989 the number of empty plots had declined 33 percent, and mean cover increased from 1 to 22 percent. No submersed or floating-leaved vegetation was found in the unplanted areas.

Most successful planting appeared to occur in zones 3 and 4. In 1987, 68 percent of the planted sample plots had vegetation, while in 1989, 84 percent were vegetated. Cover increased from 22 to 40 percent in 1988 and 1989. In the unplanted plots, vegetation is becoming established slowly and is dominated by *Althernanthera philoxeroides*, *Hydocotyle umbellata*, and *Typha latifolia*. Eighty-five percent of the unplanted plots were empty in 1987, 1988, and 1989.

No evaluation of the success of trees or shrubs in zone 5 was made, but they appear to be doing well. In addition, this zone was rapidly colonized by old field species (probably from the remaining seedbank). Cover actually decreased from 59 percent in 1987 to 55 percent in 1989. This decrease is primarily due to the high incidence of hog rooting damage. Cover in the unplanted plots had similar vegetation cover.

The 54 permanent transects were resampled in August 1992, but these data were not available for analysis during the writing of this report.

3 Case Study #2: Charlotte County Correctional Institute, Florida[1]

Background

In September 1984, Kevin L. Erwin Consulting Ecologist, Inc. (KLECE), was contracted by the county government to provide ecological services related to the planning, construction, and monitoring of the Charlotte Correctional Institution in Charlotte County, Florida.

The proposed site was located in southwest Florida approximately 15 km north of Fort Myers (Figure 4). Working with aerial photographs, a preliminary site evaluation was conducted in October 1984, which included observations on threatened and endangered flora and fauna, drainage patterns, and the distribution of upland and wetland habitats within the subject property. Historically the 113-ha site (Figure 5) was covered by pine flatwoods interspersed with isolated herbaceous marshes, mesic oak hammocks, and high wet prairies. The area had been subjected over time to agricultural development, particularly clearing, drainage, and cattle grazing. Surface water on the site had been impounded and hydroperiods altered by surrounding berms and ditches which limited drainage from the property. Other than limited natural overflow, water level within the property was controlled by an off-site agricultural pump that discharged into a slough at the south end of the property. Based on these initial observations, the project planner was advised on a facility location and configuration that maximized retention of desirable habitats, specifically high-quality wetlands, mature pine flatwoods, and mesic oak hammocks (Figure 6).

In February 1987, the Florida State Department of Environmental Regulation concluded that wetlands within the site were diked off and not within the landward extent of waters of the state, and therefore were not

[1] Written by Kevin Erwin, Kevin L. Erwin Consulting Ecologist, Inc., Fort Myers, FL, and Robert Rutter, Florida Department of Environmental Protection, Punta Gorda, FL.

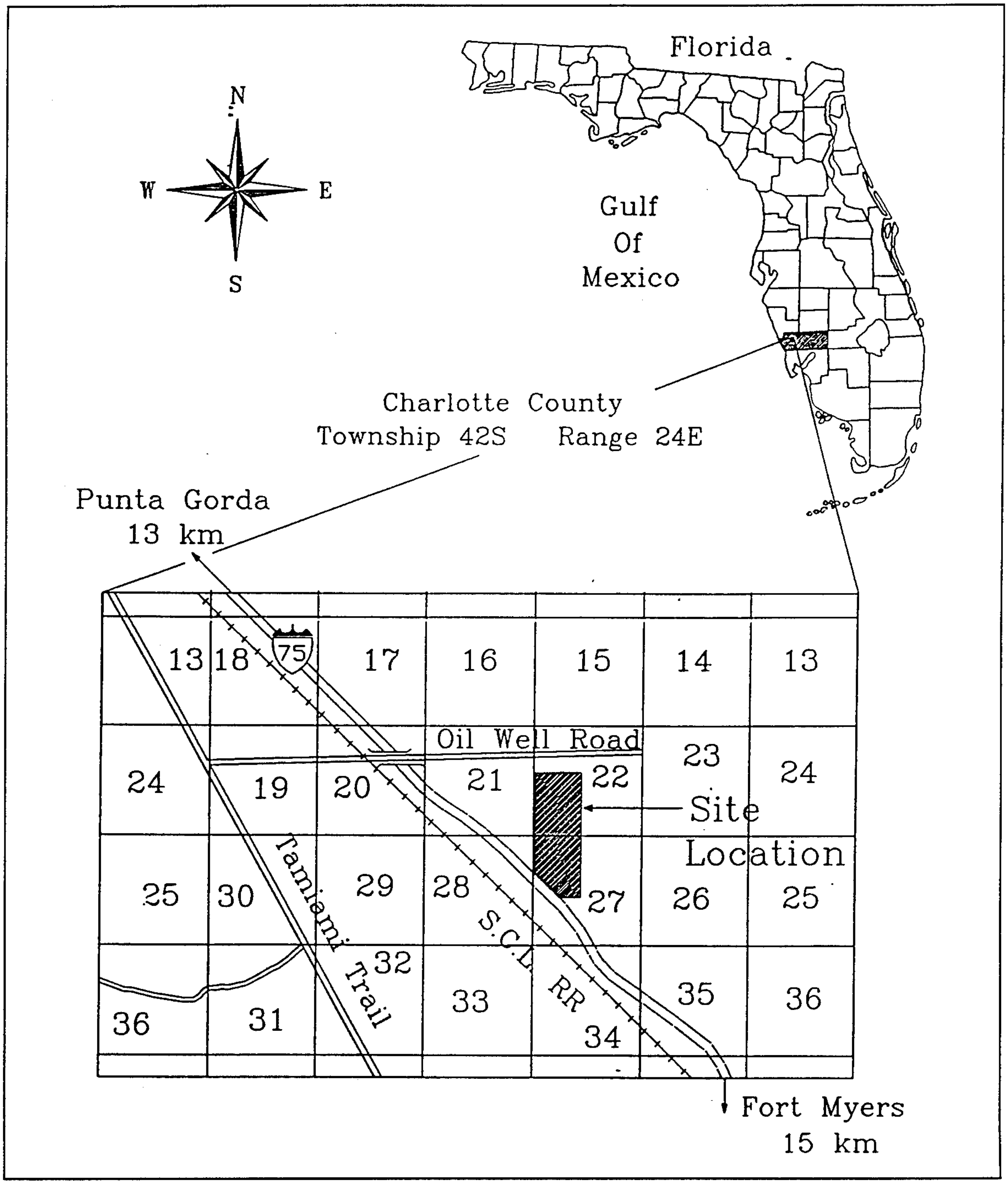


Figure 4. Location of Charlotte County study area

jurisdictional. However, because there were wetlands present onsite that would be lost due to construction, the USACE and South Florida Water Management District required one-to-one in-kind mitigation. This involved the creation of approximately 23 ha of depressional herbaceous wetlands elsewhere on site, as well as the preservation of some existing wetlands, upland pine forest, and oak hammocks.

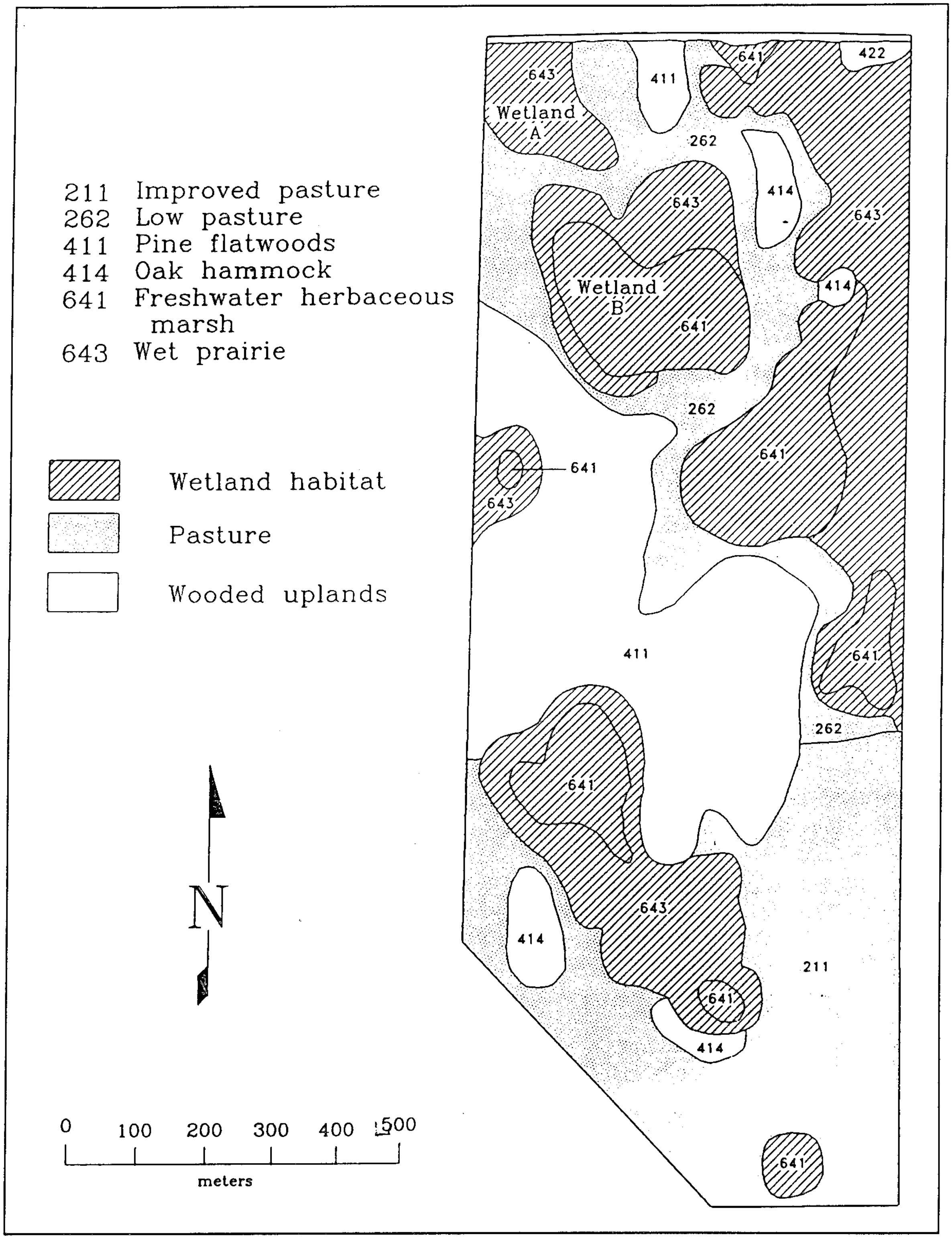


Figure 5. Charlotte County study site prior to construction showing types and distribution of habitats

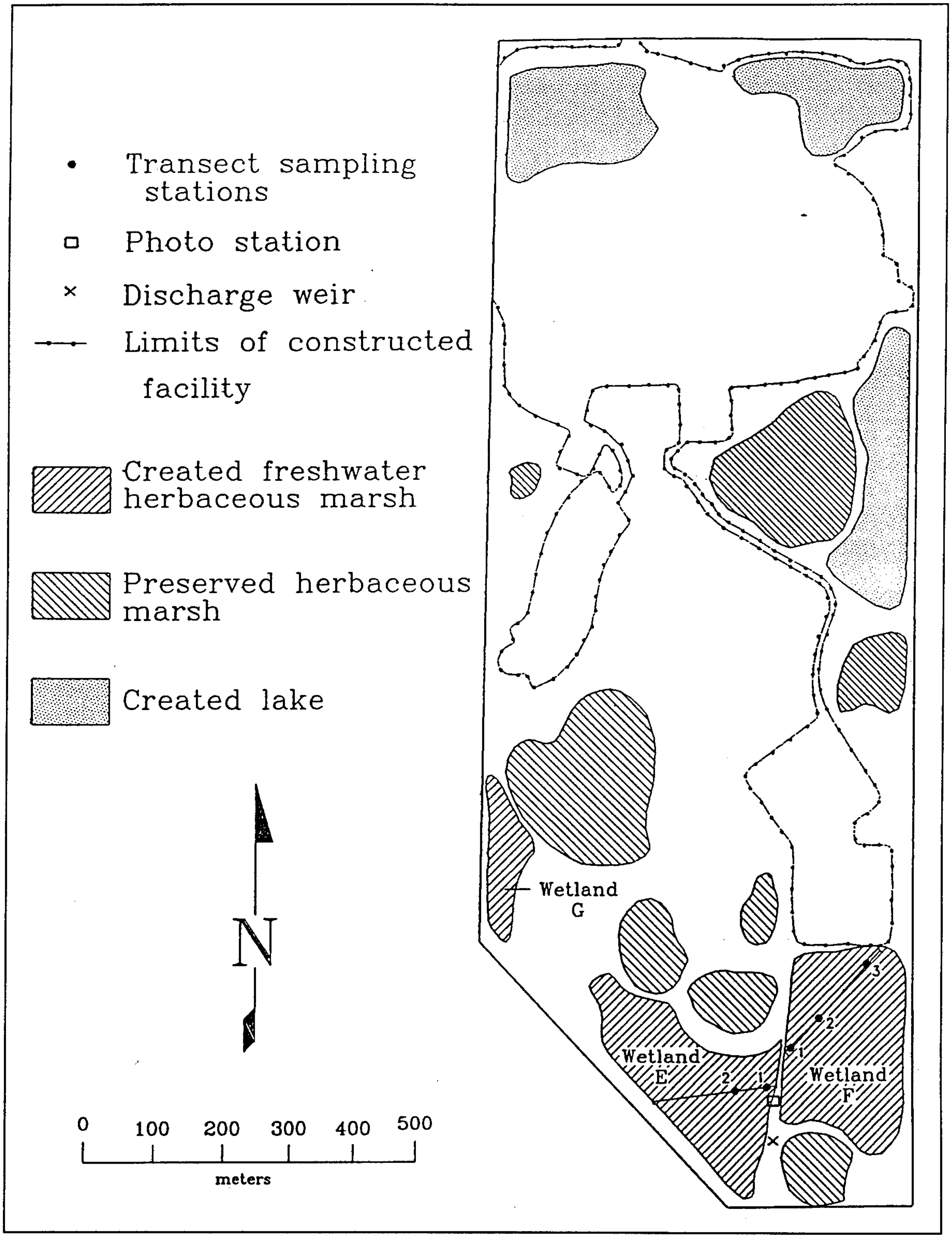


Figure 6. Charlotte County study site after construction showing generalized layout of the correctional facility and major preserved and created wetlands

Planning

KLECE prepared a mitigation plan in March 1987 that detailed the wetland mitigation required to compensate for the loss of 23 ha of shallow freshwater marsh habitat. The proposed mitigation area was located at the southern end of the property, primarily because most of this area had been converted to upland improved pasture (Figure 5) and, thus, had reduced habitat value. Three new wetlands that would be hydrologically interconnected were planned. The configuration of the contructed marshes was designed along a uniform contour (Figure 6) at an elevation corresponding to the deeper wetland macrophyte communities within adjacent natural marshes. The plan was not designed to duplicate the contours or the macrophyte communities of the natural marshes. The wetlands were designed to protect the surrounding undisturbed oak hammocks from inundation during normal seasonal high water levels. Water levels within the wetland mitigation area were to be regulated by a fixed-notched weir discharge structure designed to provide water depths of 9 to 91 cm and hydroperiods of 6 to 9 months that were similar to those of the existing natural wetland areas onsite.

Several options were available for establishing herbaceous vegetation in the newly created wetlands. These included natural invasion and colonization, hand sprigging of nursery stock, and mulching. At this time, March 1987, mulching was an innovative, yet poorly, researched and documented procedure for establishing desired vegetation in newly created or restored freshwater herbaceous wetlands. However, KLECE had several years of experience with the efficacy of the method in phosphate mine reclamation in south-central Florida. In 1982, one portion of a newly contoured wetland was topsoiled with donor mulch, whereas an adjacent area was allowed to revegetate naturally. Percent cover and species richness of the mulched and naturally regenerated areas were monitored quarterly over a period of 4.5 years. The results of this study indicated that the mulching method was extremely effective for rapidly establishing emergent aquatic vegetation (Erwin and Best 1985), although some degree of control was necessary in the early stages to prevent the invasion of undesirable species (i.e., *Typha* spp. and *Ludwigia* spp.).

Since onsite wetlands were going to be lost due to construction of the facility and in light of the previous success of the technique in establishing herbaceous wetlands, it was decided that mulching was the most appropriate planting technique for this project. Excavation of the wetland mitigation area and the collection and spreading of the donor mulch were to be coordinated in order to reduce the exposure time of the newly contoured areas. This would reduce the opportunity for infestation by unwanted species and preclude or reduce the period of stockpiling. Based on experience, stockpiling longer than several weeks adversely impacts mulch and reduces the viability of desirable broadleaf species, perhaps through composting that may oxidize propagules or enhance fungal growth.

Site Assessment

Site assessments were performed prior to excavation of the donor and mitigation marshes. Substrate and hydrological characteristics of the marsh areas were compared to determine the target elevation contours for excavation of the mitigation marsh. Vegetation distributions and organic soil depths in the donor marshes were further characterized to determine the quality and quantity of available mulch.

Substrate and hydrologic regime

Six soil series were present onsite. All soils were considered hydric by the U.S. Department of Agriculture, Soil Conservation Service (1991): Copeland (designated 45), Floridana (51), Hallandale (6), Pineda (26), Wabasso (35) and Winder (62) (Henderson 1984). Donor wetland soils were in the Winder series, characterized by Henderson (1984) as fine-loamy, siliceous, hyperthermic Typic Glossaqualfs. They are deep, poorly drained, slowly permeable soils that formed in thick beds of sandy and loamy marine sediments. In most years, under natural conditions, the water table is above the surface for about 3 to 6 months or more. The water table is 25 to 102 cm below the surface during extended dry periods.

Soils in the mitigation area were in the Pineda series, similarly characterized as loamy, siliceous, hyperthermic Arenic Glossaqualfs. They are deep, poorly to very poorly drained, slowly permeable soils that also formed in thick beds of sandy and loamy marine sediments. In most years, under natural conditions, the water table is within a depth of 25 cm for 2 to 4 months and at a depth of 25 to 102 cm for more than 6 months. It recedes to a depth of more than 102 cm during extended dry periods. During periods of high rainfall, the soil is covered by a shallow layer of slowly moving water for periods of about 7 days to 1 month or more. In depressions, the soil is ponded for about 3 to 6 months or more in most years.

Donor marshes

In early October 1987, qualitative surveys were made of the two wetlands (designated A and B in Figure 5) from which the mulch was to be obtained. An effort was to be made to transfer mulch to areas in the mitigation wetland that were hydrologically similar to the area in the donor marsh from which it was collected. Each donor wetland was delimited into inner, middle, and outer zones that corresponded to dominant macrophyte communities, organic content of soil, and seedbank potential. Deeper (inner) areas of the marshes with desirable vegetation and a thicker stratum of organic sediments were considered to have the highest value for use as donor mulch material. Zones were marked with survey stakes which indicated the depth of excavation required. Bottom contours were not determined. At the time of the survey, water depth ranged from 16 (outer zone) to 37 cm (inner zone) in Wetland A, and 8 to 46 cm in Wetland B.

Mulch Collection, Transfer, and Application

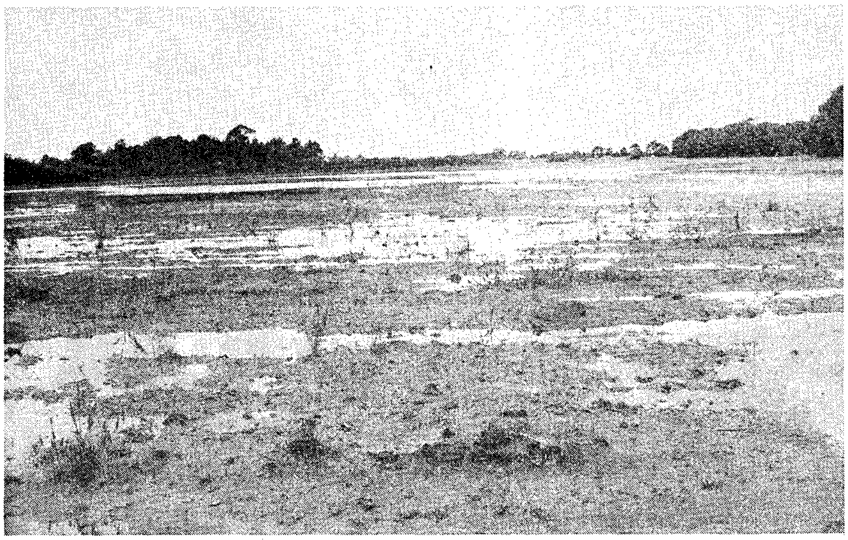
The donor wetlands were dewatered to ensure that the mulch could be removed to the proper depth using heavy equipment. Grading, stripping, and stockpiling (in piles no deeper than 60 cm) of the seedbank topsoil had just begun in mid-October when unseasonably heavy rains inundated the construction area. Total rainfall for the month of October is normally around 9.7 cm; in 1987 total rainfall measured 15.9 cm. Waist-deep water in the wetlands halted mulch removal. Because the Water Management District had not permitted offsite pumping and because November was also an unusually wet month, it was early 1988 before water levels had receded to the point where wetland-related construction activities could resume.

In January 1988, a meeting was held with the earthwork contractor to outline the process of excavating the new wetlands (Figure 6 e, f, and g), removing the donor mulch according to zone, keeping the types segregated, and relocating the mulch directly to designated areas within the wetland mitigation area. Excavation and contouring of the new wetlands began in early spring. The mulch material was being removed by backhoe and loaded onto dump trucks and pans, when heavy rains in March again inundated the mitigation area. This was problematic since the desired condition for mulch spreading requires that the wetland mitigation area be excavated but not inundated. In addition, inundation interfered with the elevation contour inspections to ensure compliance with project design specifications. Consequently, the mulch was again stockpiled while water levels receded in the newly contoured wetlands. In early May, after approximately 8 weeks of being stockpiled, the mulch was transported in pans to the mitigation area (Figure 7) and spread to a uniform thickness of about 8 cm using motorgraders and small dozers. Repeated handling of the mulch material, however, resulted in the mixture of the segregated material from different zones in the donor wetlands. Although wetland soil conditions were not recreated, enough mulch material was spread to inoculate the area with native biota and soil organic matter.

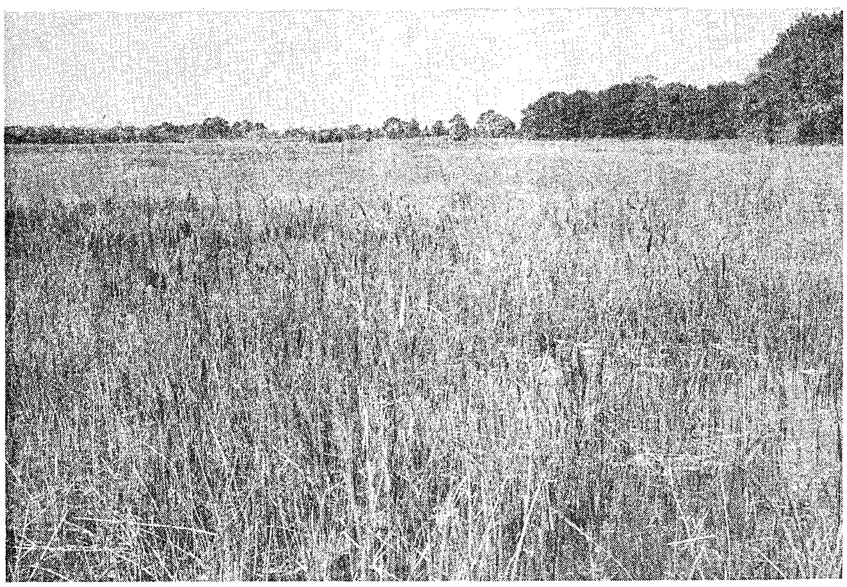
Monitoring

Temperature and water levels following mulching

Charlotte County lies in the transition zone between the humid subtropical climate that prevails over much of the southeastern United States and the quasi-tropical climate of southernmost Florida; freezing temperatures are rare. No freezing temperatures were recorded during the stockpiling period (20 October 1987 to 7 May 1988). The lowest daily temperatures in December 1987 and January, February, and March 1988 were 3 °C, 1 °C,



a. Contoured prior to mulching



b. Two growing seasons following mulching

Figure 7. Photos of the Charlotte County mitigation wetland

2 °C and 4 °C, respectively. The highest daily temperature recorded was 32 °C in October 1987 and April 1988.

Rainfall in Charlotte County averages between 127 and 140 cm per year. Although some rainfall normally occurs every month, there is a distinct rainy season extending from May through September and a low rainfall season from October through April. About 60 to 65 percent of the annual rainfall occurs during the late spring-summer rainy season (Fernald and Patton 1984). Rainfall following mulching in 1988 corresponded closely with the norm; 132 cm fell during the year, 66 percent during the wet season. Total rainfall in the following 2 years was below normal, 103 cm and 83 cm in 1989 and 1990, respectively. However, rain fell every month during these 2 years, with 70 percent occurring during the wet season and 30 percent during the dry season.

Vegetation development

Monitoring requirements for this project were not research oriented, but rather directed toward determining compliance and estimating the success of the mulching technique. A single transect was established in each wetland and a permanent 3 m square sampling quadrat was established in each major vegetation zone (Figure 6: 2 in wetland E, 3 in wetland F). The mean percent cover by species and total vegetation in 1988 and 1990 are compared with the visual estimates of cover in the donor wetlands in Table 1.

Rain fell within 2 weeks of mulching and maintained saturation of the sediments and pooled to depths of 38 cm in depressional areas. Growth of emergent vegetation occurred within 6 weeks of mulching. By mid-July, standing water covered approximately 50 percent of Wetland E and 85 percent of Wetland F; all exposed soil was saturated. By late July the wetlands were totally inundated. Spikerush (*Eleocharis* spp.) became dominant throughout all the wetlands by September. Cattails (*Typha* spp.) were first observed in late July, and control of this plant by hand-removal was initiated in October.

The qualitative reconnaissance of the donor wetlands in October 1987 noted 29 taxa, 11 of which were relatively abundant in terms of percent cover (Table 5). By September 1990, 124 weeks after mulching, 16 taxa (including *Lyngbya*) were recorded among the five sampling quadrats in created wetlands E and F; seven of these were relatively abundant in at least one quadrat. This difference in species richness may reflect less area being surveyed, the uniform contour, and the relatively young age of the created wetlands. It is likely, however, that the loss in species richness was due in part to the extended stockpiling, repeated handling of the mulch, and placement of mulch in inappropriate hydrological zones in the created wetlands.

The most notable difference between the donor and created marsh vegetation communities was the absence of *Ceratophyllum* (coon-tail) and the aggressive growth and predominance of spikerush (approximately 95 percent *Eleocharis interstincta*, 5 percent *E. cellulosa*) throughout the created wetlands. Why these species were so successful is unknown. It may be that extended (up to 28 wk) stockpiling and repeated handling of the mulch adversely affected the viability of other species (e.g., *Ceratophyllum, Pontederia* and *Sagittaria*), reflected subtleties of hydroperiod, or perhaps, *Eleocharis* is simply a successful early colonizer. The condition persists to the time of this writing (July 1994), although *Pontederia* and *Sagittaria* are gradually

Table 5
Species Occurrences in the Mulch Donor Wetland and the Mulched Wetland the Year of Treatment (June 1988) and After Two Full Growing Seasons (September 1990) at the Charlotte County Mitigation Site

		Mulched Marsh[1]	
		Year	
Species	Donor Marsh[2]	1988	1990
Aster sp.	+		
Bacopa caroliniana	*	+	5
Ceratophyllum sp.	*		
Cladium jamaicense		10	
Crotalaria sp.	+		
Cyperus sp.	+	+	4
Eleocharis spp.[3]	*	35	72
Eleocharis vivipara		2	3
Eragrostis atrovirens			+
Fuirena sp.	*	+	
Hydrocotyle umbellata	+	+	+
Hyptis alata	+		
Leersia sp.	*		
Lyngbya sp.	+		
Nymphoides aquatica	+	2	+
Panicum hemitomon		+	2
Paspalum sp.		4	
Pluchea rosea			+
Polygonum hydropiperoides		+	
Pontederia cordata	*	8	18
Proserpinaca palustris		+	
Rhynchospora spp.	*	18	11
Sagittaria sp.	+	4	13
Scirpus sp.	*		
Sisyrinchium sp.		+	
Stillingia aquatica	+		
Thalia geniculata	+	16	10
Typha spp.		+	+
Utricularia spp.[4]	+	4	15
Xyris sp.	+		
Average Percent Cover		90	100
Total Taxa	20	19	15
Taxa in Common w/Donor		11	10

[1] Visual estimates of species dominance were taken in the donor marshes (+ - present; * - abundant).
[2] Averages of percent cover estimates in 5 plots are given for the mulched marshes.
[3] Includes *E. cellulosa* and *E. interstincta*.
[4] Includes *U. cornuta* and *U. purpurea*.

becoming more common. *Utricularia* (bladderwort), first recorded in November 1988, is the dominant submerged plant species.

The wetlands created as mitigation for construction of the Charlotte Correctional Institution were considered functional after the first growing season and met permit success criteria in approximately 28 months. The mulching procedure rapidly established the desired herbaceous vegetation (Figure 7) with no significant invasion by *Typha* spp. *Typha* never exceeded 2 percent cover due to the rapid coverage by preferred species and early control efforts. Utilization of the wetlands by aquatic macroinvertebrates, fish, and other wildlife (including three protected bird species) was comparable to that in nearby natural marshes (KLECE 1989-1990).

Relative costs of mulching

Among methods for establishing emergent vegetation in a newly contoured depressional wetland, natural colonization is the least expensive. Natural colonization does occur, but the rate of aerial coverage and species accrual is slower (KLECE 1983-1987, Erwin and Best 1985). This in turn extends the monitoring requirements until 80 percent coverage by desirable species is attained. In addition, there is little control over species composition, and undesirable species can rapidly dominate the vegetation.

Hand-planting of selected emergent species, typically on 0.9-m centers, is a second option. At present the cost is 75 cents each to purchase and have the smallest 5.1-cm plant unit installed. Twenty-three ha would require 274,912 units, at a total cost of $192,438, and would take approximately 52 days to plant. At this density, 80 percent coverage (of *Pontederia*, for example) in south Florida could be achieved in 36 to 60 months. Control of nuisance species may be necessary.

Mulching incurs expenses associated with the delineation, collection, transport, and spreading of the mulch, which in this project were roughly $6.00 per cubic yard (0.76 cu m). A total of 22,909 cu yd (17,502 cu m) was required to cover 23 ha with 7.6 cm of mulch at a cost of approximately $137,454. Eighty percent coverage was obtained in 28 months. Early control of *Typha* was necessary but minimal. As evidenced by this project, mulching does not necessarily ensure (at least in the short term) that the donor marsh plant community will be replicated in the recipient wetland; however, the concomitant introduction of sediment-associated micro-and macrofauna may "jump-start" functional integrity. At another mulching project in nearby Manatee County (82 km northwest of the Charlotte County Site), 80 percent cover was achieved after one growing season. The mulch was not stockpiled, and there was more coverage by broadleafed genera; i.e., *Pontederia* and *Sagittaria*.

4 Case Study #3: West Eugene Native Wetlands Restoration Project[1]

Background

Prairie wetlands once occupied much of the low-lying parts of the Willamette Valley, Oregon. The endemic wet prairie community was dominated by tufted hairgrass, *Deschampsia caespitosa*, and an assortment of sedges, rushes, grasses, and forbs. Forested wetlands, dominated by Oregon ash, *Fraxinus latifolia*, were also prominent features of the valley occupying riparian strips and adjacent poorly drained bottomlands. The prairie wetlands were historically maintained by Indian-ignited and natural fires. When settlers first acquired land in the Willamette Valley, they used it for agricultural purposes; wet prairies were grazed or harvested for hay. Wetlands were drained; sloughs were filled or dredged; creeks were channelized, and forests were logged to provide more usable land for agriculture and livestock grazing (Savonen 1988). The size and extent of native wet prairie and mature Oregon ash habitats have been drastically reduced. In more recent times, grazing and hay harvesting have sustained the remaining wet prairie community and prevented the colonization of forest vegetation (Alverson 1990).

In 1989, Fishman Environmental Services was contracted to establish and monitor native wetland vegetation in the West Eugene Wetlands Project. The primary objectives of the project were to restore two diminishing native wetland habitats (6.9 ha of emergent/wet prairie and 4.2 ha of forested wetland) and to document the effectiveness of restoration techniques utilizing native plant materials.

[1] Written by Paul Fishman, Fishman Environmental Services, Portland, OR, Mark G. Wilson, Portland, OR, and Christine Galen.

Site Description

The study site is located near Eugene in the Willamette Valley, Oregon. It was selected and purchased by Spectra-Physics, Inc. in the summer of 1989 for a wetland mitigation project. The site straddles Amazon Creek just northwest of the Spectra-Physics plant location (Figure 8). Amazon Creek was channelized, and levees were constructed in the late 1940's and early 1950's. In addition, a new channel was constructed by the USACE to route most of Amazon Creek west to Fern Ridge Reservoir, thereby reducing seasonal flooding and increasing agricultural opportunities. The site was selected after field examinations of vegetation, soil, and hydrologic characteristics at numerous properties along the Amazon Channel drainage. Site selection criteria were based on a high of degree of disturbance (i.e., no remnant wet prairie on the two south fields), accessibility, and habitat interspersion (bordered and traversed by several water features).

The project site was divided into three unequal sectors (Figure 9): north (N), southeast (SE) and southwest (SW). The Amazon Creek separated the N sector from the SW and SE sectors. The SW and SE sectors were separated from each other by another channelized creek, Dead Cow Creek. Preliminary investigations were made of site conditions during the winter and spring of 1989/90.

Hydric soils were present throughout the site. Dayton and Natroy series are the dominant soil types (SCS 1987). These soils are generally deep and poorly drained silty clay loams that perch water during periods of heavy seasonal rainfall. They are subject to ponding due to slow permeability. The Eugene area receives an average 117 cm of rainfall annually. Water ponds on the site to approximately 45 cm deep and is present from November through mid-June in normal rainfall years. Soils remain saturated in some site locations through mid-July.

Vegetation on the mitigation site prior to construction was different in each of the three sectors. The N sector was an abandoned agricultural field dominated by tall fescue, *Festuca arundinacea*, and tufted hairgrass. The SE sector was a monoculture of 1.5- to 3.0-m tall reed canarygrass, *Phalaris arundinacea*. The SW sector was a cultivated annual ryegrass, *Lolium multiflorum*, field that had been cultivated for over 50 years. Dominant weeds in the SW field included barnyard grass, *Echinochloa crusgalli*, and toadrush, *Juncus bufonius*.

Site and Restoration Technique Assessments

Once the mitigation site was selected, it was necessary to study site conditions more thoroughly and to find native plant sources before undertaking the project. Three projects were initiated during the winter and spring of 1989 to

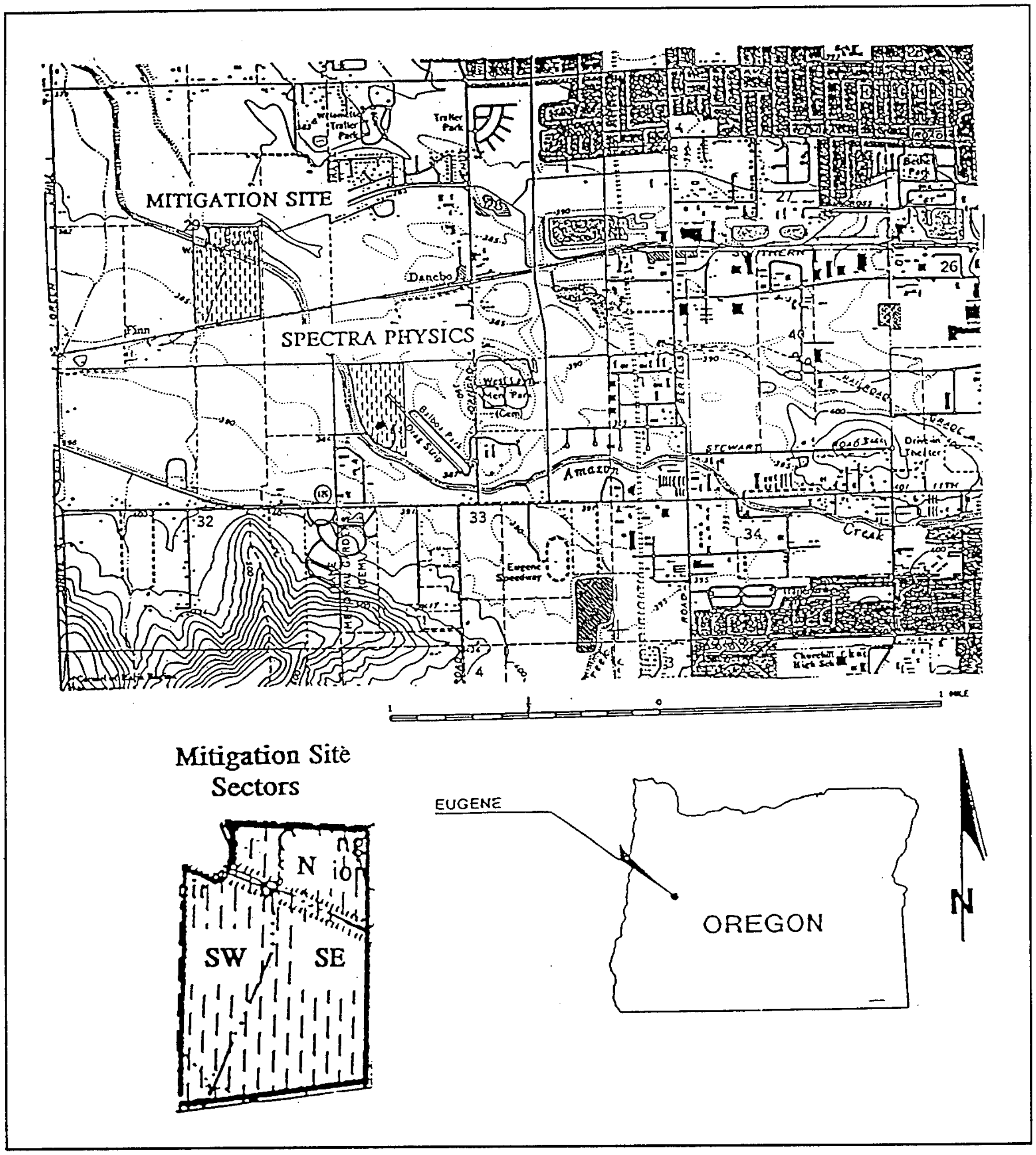


Figure 8. West Eugene Wetlands Research Project, site location and project area

1990: 1) hydrology of all three sectors was monitored to determine if existing hydrologic conditions were suitable to support wetland habitat restoration, 2) winter dormant Oregon ash seedlings were transplanted to the mitigation site to determine if transplanting seedlings would be successful, and 3) the soil seed bank was analyzed to determine its species composition.

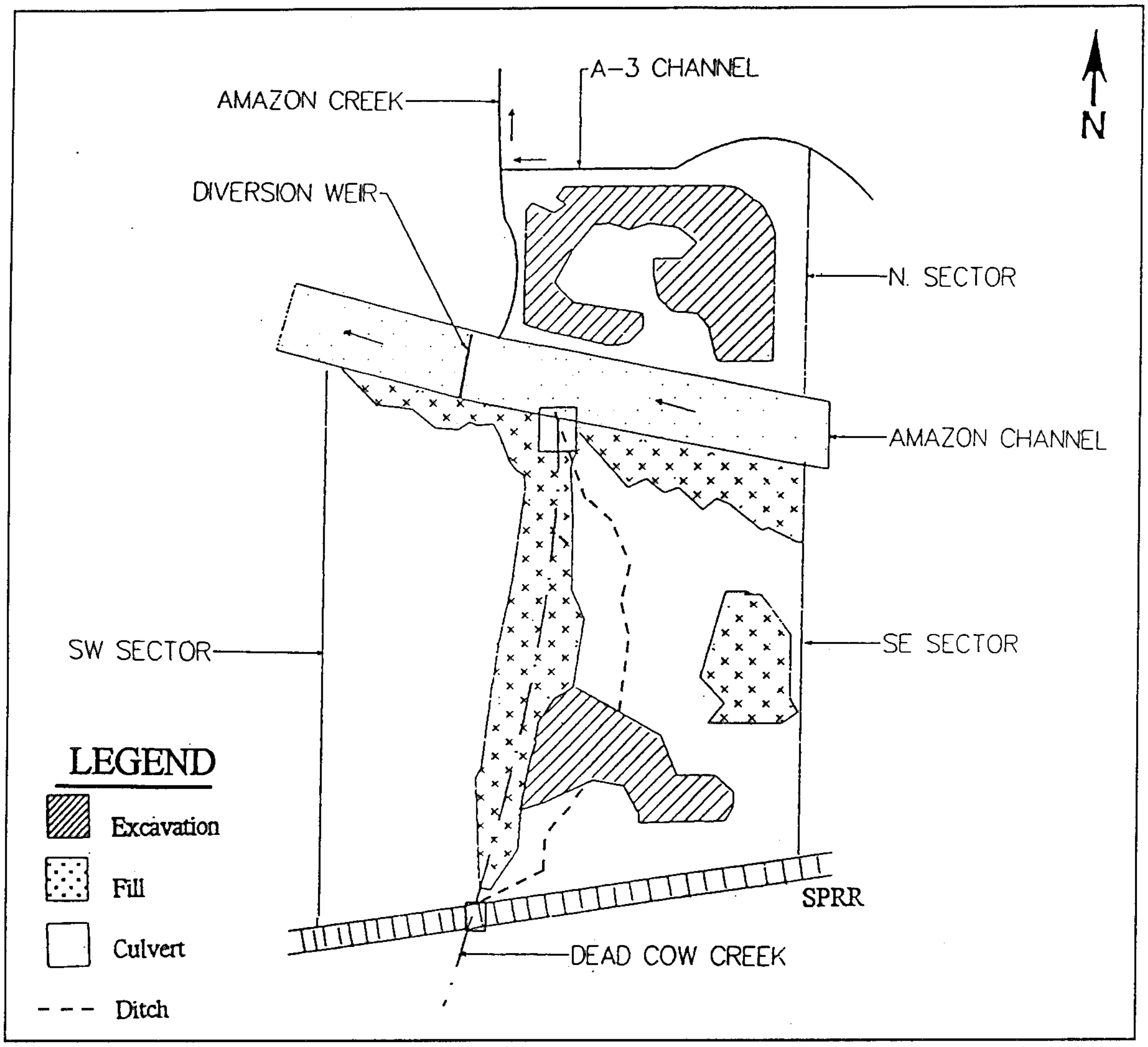


Figure 9. West Eugene Wetlands Research Project, site grading

Hydrology

Wetland hydrology was monitored using a series of 10 piezometers. The piezometers were constructed of PVC casing screened below 1.5 m and extending approximately 3 m below the ground surface. Piezometers were installed in each sector of the mitigation site during 1989 to determine the hydrologic characteristics of each field. Depth to water was measured in each installation using an electronic water level probe. Measurements were taken approximately once per month except for weekly measurements during March and April. Depth of surface water or a qualitative estimate of soil moisture were also recorded for each well location.

Water generally was >0.6 m below the ground surface at all locations and all seasons, with the exception of two wells where the water table was higher.

Standing water was present at most well sites, and soils were saturated at all locations during the winter and early spring.

Wetland hydrology on the mitigation site is the result of surface water accumulation rather than groundwater elevation. The poorly drained clay soils of the site have low permeability and pond water for significant duration during winter and spring. Diking associated with channelization of the Amazon Channel and Dead Cow Creek restricts surface drainage that historically flowed to these streams and prevented seasonal flooding of the mitigation site. Data from this hydrology study were used during the mitigation planning process to determine areas that required excavation.

Oregon ash transplants

Oregon ash, *Fraxinus latifolia*, bears a prolific crop of viable seed each year and is considered an important colonizing tree within Willamette Valley wetland areas subject to seasonal inundation. Ash is among the first invading pioneer species observed in wet prairies undergoing succession and for this reason is considered undesirable in areas being managed as prairie. The Nature Conservancy (TNC) manages a wet prairie preserve at Willow Creek in West Eugene which is located approximately 5 km south of the Spectra-Physics wetland mitigation site. Restoration of wet prairie on the preserve is one of the management goals. TNC granted permission to dig bare-root ash seedlings from preserve areas to be restored as prairies. These seedlings were to be test planted in various locations of the mitigation site to assess the potential for using them to establish forested wetlands.

On February 19, 1990, approximately 100 well-branched Oregon ash seedlings less than or equal to 0.5 m in height were transplanted from an area adjacent to the Willow Creek floodplain to the three different sectors on the Spectra-Physics mitigation site. Plants were dug after air temperatures were above freezing, and the bare-rooted plants were kept moist and protected in wet burlap. Ten trees were planted approximately 1.6 m apart at each of 10 transplant sites. The ground surrounding five trees at each location was scalped to reduce competition from grasses, and the ground surrounding the remaining five trees was left in grass cover.

The sites were revisited on September 5, 1990, to assess the survival and vigor of the Oregon ash transplants. Out of 100 trees planted, 78 were located during the September 5 field visit; 10 percent of these trees had died. The remaining live trees appeared healthy. None of the plants showed new growth from the growing tip; their growth was stunted, and their energy directed toward survival and maintenance. For comparison, Oregon ash trees growing in the floodplain where these transplants were collected averaged approximately 2 cm of growth during 1990. No conclusions were made regarding scalping the ground; it did not seem to influence tree survival or vigor during the first growing season. Transplanting winter dormant ash seedlings was successful; however, trees in drier soils of the N and SE sectors showed less vigor than transplants in moister sites.

Seed bank analysis

The SE and SW sectors of the Spectra-Physics mitigation site had historically either been plowed, cropped, and/or grazed. These agricultural practices result in the accumulation of non-native seeds in the seed bank. Seedbank analysis was necessary before planning for wet prairie restoration could begin. The seedbank testing goals were to determine the extent of seedbank contamination with persistent exotic species; discover the existence/identity of buried native seedbank; formulate possible seedbank management strategies; and establish a means of measuring the results of those proposed management strategies. Literature on the influence of seedbanks to prairie restoration was reviewed. Testing goals and a limited seedbank sampling protocol were formulated for each field.

Six samples were collected. Two samples were collected from three locations in each field: one from mineral soil surface to 7.5 cm depth and another from 7.5 to 15 cm depth. Each sampling location was established at a groundwater test site in order to facilitate follow-up sampling from the same locations.

Soil seedbank samples were collected on July 26, 1990. Analysis of bulked randomly selected 50-g samples was conducted at the Oregon State University Seed Lab in Corvallis, OR. Identification of all seeds was requested, but seeds identified as "crop" and "weed" were the primary species identified. A few "crop" and "weed" seeds identified, however, were native wet prairie and emergent wetland species. No native grass seedbank was detected. In the SE reed canarygrass sector, reed canarygrass seed dominated 2 of the samples taken from 0 to 7.5 cm. The third sample contained a small amount of wild buckwheat. At 7 to 15 cm reed canarygrass, mustard, *Brassica sp.*, and forget-me-not, *Myosotis sp.*, dominated two samples. The third sample did not contain any detectable seed. In the SW ryegrass sector, ryegrass seed dominated all of the samples from 0 to 15 cm. Meadow foxtail, *Alopecurus pratensis*, bentgrass, *Agrostis sp.*, barnyard grass, *Echinochloa crusgalli*, and American sloughgrass, *Beckmannia sysigachne*, were also present. These results indicated the high probability for the failure of native prairie restoration unless exotic seedbank control measures were implemented prior to planting native species.

Restoration Site Plan Development

Restoration project goals

The primary restoration goal of the Spectra-Physics Wetland Mitigation project was to restore two diminishing native wetland habitats: emergent/wet prairie and forested wetland. The goal was to be achieved by restoring natural hydrology to the site and establishing native plant associations where appropriate.

Restoration project planning

A conceptual site plan was submitted to and approved by state and federal agencies during the wetland permitting process in 1989. In May 1990, a preliminary work schedule was drafted and the Spectra-Physics wetland mitigation design team began work on a site grading and planting plan. The design team included civil engineers, wetland ecologists, a horticulturist, and a landscape architect. The team compared elevation and hydrology data collected during site assessments with existing emergent and forested wetlands in an attempt to match the hydrologic regime with the proposed grading plan. Field observations were used to check and adjust elevations for the final grading plan. In June 1990, a grading plan, template planting plan, and schematic cross section illustrating plant community relationships were completed.

During the remaining summer of 1990, a mitigation site plant list was prepared, and contract growing agreements were finalized with a nursery for the supply of all woody plant materials except willow, ash, and cottonwood. A woody plant list was developed from mitigation and donor site inventories and other West Eugene vegetation surveys. The final contract documents and specifications for the separate site construction and planting contracts were also finalized and sent out for bid. Negotiations also began with a local grass seed farmer for field burning, plowing, and seeding and with a local farm services company to apply herbicides. In late August 1990, construction and planting contracts were awarded and preconstruction meetings were held with each contractor. A local firm with extensive road construction and site grading experience was awarded the mitigation construction contract; a small local firm specializing in reforestation was awarded the planting contract. Construction supervision was the responsibility of the engineering firm that was the prime contractor to Spectra-Physics for the mitigation project; the ecology and natural resources management firm and horticulturist under subcontract to the engineering company were responsible for oversight of the planting contract, farming contracts, and nursery plant acquisition.

Sodmat and wetland sod transplant plan

During May and June of 1990 research was also carried out by the project horticulturist on the subject of wetland soil and sodmat transplanting. An experimental procedure was proposed for transplanting emergent marsh and wet prairie from the Spectra-Physics donor site to the mitigation site during the late summer dormant period. This procedure, using modified techniques first developed in the United Kingdom[1] and the eastern U.S.[2,3], included two methods: the careful excavation and transplantation of large intact slabs of selected herbaceous wetland emergent vegetation and soil (sodmat), and transport and spreading of wetland soil/seedbank. Final transplanting details were to be worked out with the assistance of the mitigation construction contractor.

Exotic plant management plan

The need for an exotic plant management plan was apparent from the results of seedbank analyses. The success of the project could be negatively influenced by seedbank competition and other exotic propagules in the substrate.[4,5,6, and 7] The initial plan was to apply herbicide on the south sectors followed by a prescribed burn in the late summer. Unfortunately, it was impossible to obtain a burn permit in 1990.[8] The final plan proposed different treatments for each sector. The SE sector would be sprayed with herbicide twice in the summer of 1991 followed by a burn. In the summer of 1991, the SW sector would receive two herbicide treatments followed by fallowing. Herbicide treatment would prevent seed formation, and fallowing would help deplete the seedbank supply.

Native seed harvest methods

During the summer and early fall of 1990, two experimental seed machine harvest techniques were tried at three local wet prairie sites that were relatively free of exotic species contamination. The goals of these tests were to determine if modified grass seed farm equipment was a cost effective means of harvesting native grass seed, and to determine if mechanized bulk seed harvest could produce results comparable to the high quality of hand harvest but at a much lower cost. A local grass seed farmer was contracted to custom harvest tufted hairgrass from one small wet prairie remnant 2 km from the

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[1] Personal Communication. (1990–1991). D. R. Helliwell, Derbyshire, United Kingdom.

[2] Personal Communication. (1990–1991). L. Sauer, Andropogon, Ltd., Philadelphia, PA.

[3] Personal Communication. (1990–1991). G. Williams, Vancouver, B. C., Canada.

[4] Personal Communication. (1990–1991). S. Aphelbaum, Applied Ecological Services, WI.

[5] Personal Communication. (1990–1991). S. Packard, The Nature Conservancy, Chicago, IL.

[6] Personal Communication. (1990–1991). P. Schram, Knox College, Galesburg, IL.

[7] Personal Communication. (1989). P. Quarterman, Eugene, Oregon.

[8] Until 1992, specific regulations governing field burning for the restoration of native prairies in the Willamette Valley of Oregon were non–existent. It was necessary, therefore, in order to burn ryegrass stubble in the SW sector, to acquire a closely regulated Agriculture Crop Waste permit. A different, less closely regulated, Construction or Demolition Debris permit was required for the burning of the Reed canarygrass in the SE sector of the mitigation site.

mitigation site. On July 12 through 14, 1990, a standard combine modified for the harvest of small seed was used to harvest approximately 90 kg of bulk grass seed consisting primarily of tufted hairgrass. Seed test results indicated that the combine harvested seed was slightly contaminated with velvet grass, *Holcus lanatus*, but cleanable. On September 20, 1990, a gas engine powered parking lot vacuum was modified to collect bulk grass and herbaceous forb seed from two smaller prairie fragments (less than 1 km from the mitigation site) that had been monitored since the spring of 1990. Samples from this vacuum collection were sent to the Oregon State University (OSU) Seed Lab for identification of crop and weed constituents. Subsequent seed identification results indicated that the vacuumed samples were contaminated with significant amounts of velvet grass and other noxious exotics making them unsuitable for use due to the high cost of cleaning.

Site Preparation

The site required excavation and construction of water control structures prior to planting to establish the planned hydrology. In addition, undesirable plant species that existed on site had to be reduced as much as possible to ensure the success of the native plantings. Site preparation activities are summarized in Table 6.

Site excavation and earthwork

Excavation and grading of the N sector was conducted during the period September 12 to 15, 1990. Soil removed from the N sector was used to recontour the dikes surrounding the SE and SW sectors (Figure 9). Areas in the center and western edge of the N sector were graded to direct overflow water from the wetland sodmat area to a culvert draining to the A3 Channel at the NW corner. Grading was designed to allow slow drainage for the future forest area (5 to 15 cm in water depth) and to emergent marsh area (45 cm water depth). Additionally, an area to be planted with forested wetland species was also graded in the SE sector. All graded areas were "topsoiled" with 13 to 25 cm of relatively clean, salvaged topsoil to meet final grade specifications.

All excess soil from the N sector was trucked to the south fields and used to create nonlinear edges along the existing dikes. A water control structure was constructed in Dead Cow Creek where it crossed the southern boundary of the mitigation site, and a connecting ditch was excavated extending from that structure to the excavated area in the SE sector designated as forested wetland area.

Table 6
Chronologic Review of Site Preparation Activities—West Eugene Mitigation Site 1989 - April 1992

Date of Occurrence	Task	N Sector	SE Sector	SW Sector
1989	Surface and groundwater hydrology monitoring	X	X	X
February 1990	Oregon ash seedling test transplanting	X	X	X
July 26, 1990	Seedbank sampling		X	X
September 12-15, 1990	Excavation and grading	X	X	X
September 15-20, 1990	Sodmat/wetland soil transplant	X		
October 1990	Fall fallowing			X
November 1990	Planting E buffer (nursery plants)	X		
November 1990	Tufted hairgrass seeding	X		
February-April 1991	Planting willow, cottonwood cuttings and bareroot ash seedlings	X		
June 1991	Herbicide treatment of reed canarygrass patches	X		
June 1991	Herbicide treatment of berms		X	X
June-September 1991	Wet prairie seed collecting (off site)			
July 5, 1991	Herbicide treatment		X	X
July 24, 1991	Herbicide treatment		X	X
August 9, 1991	Herbicide - N Sector reed canarygrass and SE/SW berms	X	X	X
September 1991	Hydroseeded berms		X	X
September 17, 1991	Prescribed bum		X	
October 1, 1991	Seed bank resampling		X	X
October 1-3, 1991	Prairie seeding		X	X
October 21, 1991	Sloughgrass seeding	X		
November 25, 1991	Planting tree/shrub containers begins		X	X
March-April 1992	Cuttings and bareroot ash plantings		X	X

Eradication/reduction of undesirable species

South sector fields. The south sector exotic plant management program, which could not be fully implemented in the fall of 1990, was modified and scheduled for implementation during the growing season of 1991. The SW ryegrass sector was plowed deeply on October 9, 1990. It was treated with Roundup herbicide on July 6 and July 24, 1991, prior to ryegrass seed maturation. A high flotation spray rig was used to apply the herbicide at the rate of 8.2 ℓ/ha with a translocation enhancer and aquatic surfactant. The SE reed canarygrass sector was treated with Roundup herbicide at the same time. On September 17, the SE sector was burned. After the burn, both the SW and SE sectors were prepared for seeding by first discing (with a heavy disc) and then harrowing to ensure a fine-textured seeding surface.

Soil seedbank samples were collected on October 1, 1991, from the 1990 sampling locations to measure the success of the exotic seedbank management program. In the SE sector, reed canarygrass seed was generally not present or reduced compared to the 1990 samples. The 1991 SE sector samples were dominated by toadrush (*Juneus bufonius*) and hyssop (*Bassia* sp.) seed. In the SW sector samples, rye grass seed was either slightly reduced or similar to 1990 samples. Toadrush seed, became a codominant.

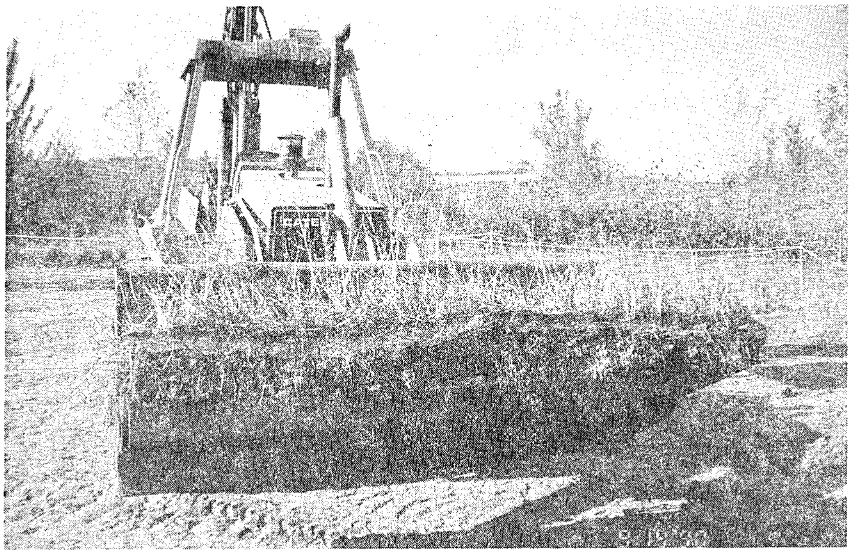
The combination of herbicide application and burning appears to have significantly reduced the reed canarygrass seed bank in the SE sector. The fallowing and herbicide application treatment of the SW sector appears not to have successfully reduced the ryegrass seed bank and resulted in a very significant increase in toadrush seed. Interviews with the farmer who had worked the SE sector until 1990 revealed that toadrush was generally targeted for herbicide application during the spring to keep it out of the ryegrass. The October 1990, plowing and July 1991, herbicide application allowed toadrush to produce a seed crop during spring of 1991.

Plantings

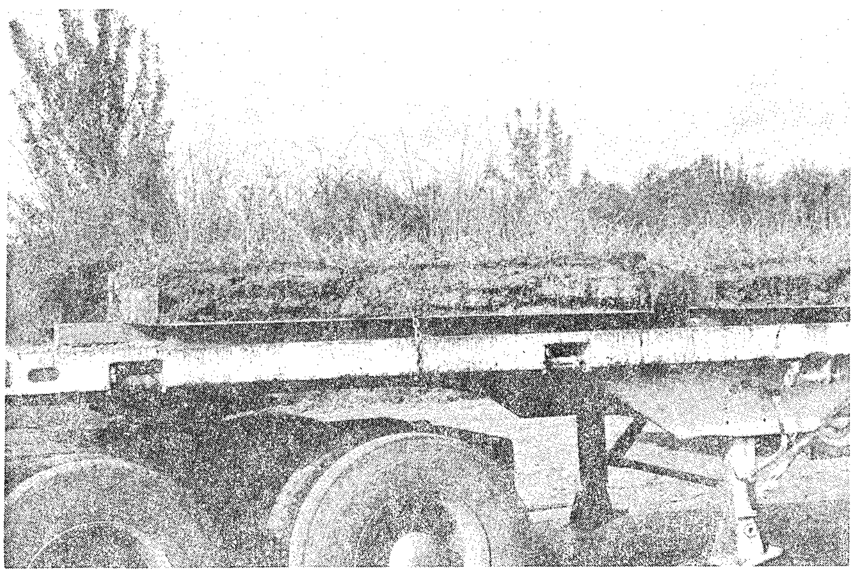
Sodmat and wetland soil transplant

During the first week of September 1990, final preparations were made to transplant the sodmats and wetland soil from the donor to the mitigation site. An approximately 0.75 acre area of high quality emergent marsh containing no invasive exotics was identified at the donor site for transplantation as 1.3 m by 2.6 m × 20 cm wetland sod mats. Additionally, approximately 0.5 ha of wetland soil consisting of primarily wet prairie grasses and forbs were identified for relocation to the mitigation site.

The sod mats were removed with a front-end loader modified with a sharp-edged steel plate and then loaded onto flatbed trucks for transport and reassemblage at the mitigation site (Figures 10 and 11). No attempt was made to reassemble the sod mats in the same positions as they were removed; however, special efforts were made not to leave gaps between sod mats. The wetland soil was loaded into dump trucks at the donor site and then spread with a road grader at the mitigation site.



a. Modified front end loader (photo by P. Fishman)

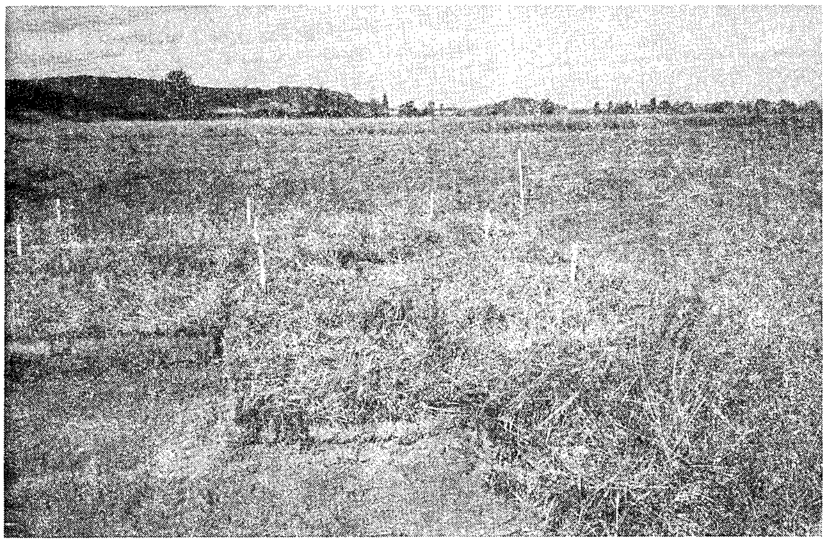


b. Sodmats in place (photo by P. Fishman)

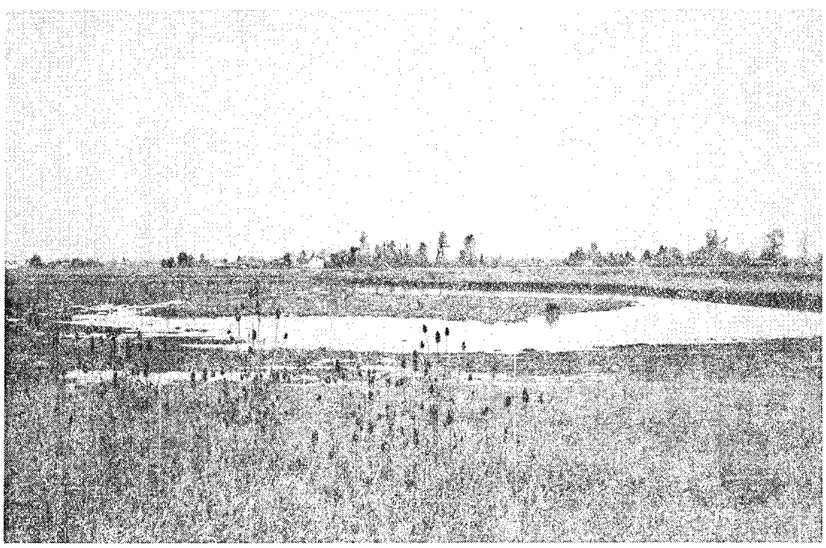
Figure 10. Sodmat transplant photos

Wet prairie plantings

Species selection. Acquisition of representative native grass and forb seeds for planting was a vital element of project planning. In 1990, no commercial sources of even the most common wet prairie herbaceous forb seed such as camas, *Camassia quamash*, existed, and only one western commercial



a. Fitting sodmats into N sector (photo by P. Fishman)



b. Sodmats in N sector, November, 2 1990 (photo by P. Fishman)

Figure 11. Sodmat transplant photos, N sector

source of tufted hairgrass was available. This commercial seed had been harvested from western Alberta, Canada; the goal of using local seed genotypes precluded its use. Consequently, the project design team needed to create its own sources for plant material.

An inventory of existing West Eugene wet prairie fragments was begun by the project horticulturist in the spring of 1990 and continued until the fall.

The vegetation of each site was characterized including species composition, dominance, and the extent of contamination of invasive species. Seed ripening dates were noted for approximately 20 of the most common prairie species in order to plan for timely future harvests.

The inventory of existing West Eugene wet prairies yielded valuable information about the species composition and dominance of wet prairie but was of limited value when used to determine seeding mix species composition for establishing a new wet prairie. With the exception of *Camassia* spp. (the only species considered prairie in the ornamental nursery trade), there was (and still is) little anecdotal experience or written information regarding Pacific Northwest wet prairie grass/forb seed phenology.[1] Also, little information was available concerning plant succession and the establishment of wet prairie habitat. The selection of wet prairie species, in the absence of scientific information, was therefore based primarily on an analysis of one year's field data.

A master species list of grasses and forbs was compiled from the data gathered in the 1990 field surveys. Species were further sorted into matrix and patch categories. The species selected as matrix were usually always present as dominants or subdominants in all prairies surveyed no matter what the size of the plot; they were also observed to be fairly ubiquitous in their hydrologic preferences. Patch species, however, were only observed as subdominant or occasional. Plants categorized as rare in the field surveys were not considered for seed collection.

After the master list was developed, it was reviewed by two local prairie experts, Ed Alverson and Kathy Connelly, and two additional criteria for species selection were considered: colonizing ability and aesthetic appeal. Prairie restoration efforts in the midwestern U.S. identified the important role of pioneer annual species in rapidly colonizing newly seeded prairies (Aphelbaum 1990, Packard 1990, Schramm 1990). Quick-growing pioneers were non-persistent "place keepers" during the first several years after planting and eventually declined as the slower growing perennial grasses and forbs grew. The aesthetic qualities of proposed grasses and forbs were also considered because our efforts represented the first attempt at prairie restoration in the West Eugene wetlands study area and also in the western Pacific Northwest. In order to best educate the public about the values of restoring a regionally significant wetland ecotype, this first attempt should not only be designed to eventually function as a prairie but also have the look of a prairie. As a result of comments received from local prairie experts, and the consideration given to colonizing and aesthetic factors, the master list was edited and became a target species list (Appendix A). Matrix grasses included two perennial species: tufted hairgrass and spike bentgrass. Matrix forbs included

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[1] While some possible phenologic similarities could be interpreted from same-genus information found in other regional U.S. and European sources (particularly those from the northeastern U.S. and the United Kingdom as *Deschampsia caespitosa* is a circumpolar species), comparisons could not be made on either the specific species or prairie community level.

three annual colonizing species: downingia, popcorn-flower, willowherb, and seven perennials. Two patch species, California oatgrass and mule's ears, were also selected.

Planting seed mix. Development of a seeding template was the next task after selecting species. A theoretical 1,800-cm^2 seeding template was devised, based on the premise that a tufted hairgrass plant to combined forb plant ratio of 1:1 was desirable. Within this template, plants of the primary matrix grass would occupy one half of the total available space (900 cm^2), and a mixed palette of matrix forbs and other grass plants would fill the remaining half.

Finally, information concerning numbers of seed per pound was sought from horticulture reference literature and seed brokers and collectors. When count information for particular species was unavailable, genus information was used. This count information was then factored into the template model and per acre seeding rates were computed using a germination percentage of 50 percent for all forbs. It was decided that small amounts of forb and grass species designated as patch would be considered optional and acquired if possible. The final seed collection species list, including seeding rates (Table 7), was developed with the understanding that it was a wish list that might be amended by weather, insect predation, and/or other unforeseen events.

Table 7
Target *Deschampsia* Wet Prairie Species and Collection Quantities for the West Eugene Mitigation Site

Matrix Community (12.1 ha)		
Category	**Weight, kg**	**Species**
Grases	27.98	*Deschampsia caespitosa* (Tufted hair Grass)
Forbs	0.65	*Aster hallii* (Hall's Aster)
	5.60	*Camassia leitchlinii* and/or *C. quamash* (Camas)
	0.09	*Epilobium watsonii* and/or *E. glandulosum* (Willow-herb) and or *Boisduvalia densiflora* (Spach)
	0.37	*Eriophyllum lanatum* (Wooly Sunflower)
	1.68	*Grindelia integrifolia* (Gumweed)
	0.65	*Plagiobothrys figuratus* (Popcornflower)
	0.37	*Potentilla gracilis* (Slender Cinquefoil)
	2.98	*Ranunculus occidentalis* and/or *R. orthoryncus* and/or *R. alismaefolius* (Buttercups)
Patch Communities (6.1 ha total)		
Grasses		*Agrostis exarata* (Spike Bentgrass)
		Danthonia californica (CA Oatgrass)
	3.73	Total
Forbs		*Downingia elegans*
		Lotus formisissimus and/or *L. pinnatus* (Deervetch)
		Saxafraga oregana (Oregon Saxafrage)
	1.12	Total
	1.49	*Wyethia angustifolia* (Mule's-ears)

Acquisition of wet prairie seed. Tufted hairgrass seed was harvested by combine in the summer of 1990. The harvested hairgrass was used for the 1990 planting of the N sector and the 1991 planting of the S sectors.

In May of 1991, seed collection specifications were prepared for hand collection of additional prairie forb and grass species seed. Species could only be collected from pre-approved locations; the percentage of seed to collect at each collection site was also predetermined. A contract was negotiated with a small Washington state firm offering custom seed collection services. Collectors used field maps and notes supplied by the project horticulturist and began harvesting seed in mid-June. Seeds were dried and sorted for planting by mid-September 1991.

An additional wetland grass species, American sloughgrass, was also acquired by recleaning "contaminated" spoils supplied by several local ryegrass seed cleaners. Its large seed was easily separated from other spoil seeds.

Wet prairie planting. The mitigation agreement specified that only trees and shrubs would be planted in the areas designated forested wetland and wetland buffer; however, after some discussion among team members, it was decided that it would be appropriate to plant a primary succession herbaceous community of tufted hairgrass. These grass plantings would serve as the dominant plant community until the canopy of the forested wetland and prairie edge plantings shaded the ground, gradually changing the composition of the wet prairie community to an array of species more tolerant of shade.

In early November, 1990, selected areas (primarily on the west side of the N sector) were hand-seeded with tufted hairgrass acquired by the combine harvest of a local prairie. The seed was sown at a rate of 1.8 kg/ha on the surface of the soil and then harrowed with a tractor-drawn light-weight spring harrow.

On October 2 and 3, 1991, the SW and SE sectors were seeded using three methods. Wet prairie species and seeding rates are included in Tables 8 and 9.

a. *Method 1.* Patch forbs and grasses were separated into two lots according to expected soil moisture preference and then seeded in portions of each field by using a hand seeder.

b. *Method 2.* Seeding equipment included a tractor-drawn modified brillion seeder, a 1,900-ℓ poly farm tank mounted on a three-point hitch, a light-weight screen harrow hitched to the seeder, and specific seed mixtures. Coarse seeded matrix forbs and/or grasses were mixed by hand, then added and mixed in a tank containing a sterile bentonite clay and water suspension. Clay-seed suspension was then pumped to the seeder, bypassing the seed box. Some seeding tubes were intentionally plugged, and all tubes were disconnected from the seed

Table 8
Actual Wet Prairie Seeding. Species and Seeding Rates, SE Sector of the West Eugene Mitigation Site

Species Name	Seeding Rate, kg
Southeast Field: *Deschampsia* Wet Prairie Seeding	
Matrix Grasses	
Beckmannia syzigachne	8.2
Deschampsia caespitosa	8.2
Matrix Forbs	
Camassia leitchlinii	0.21
Camassia quamash	1.05
Downingia elegans	0.75
Epilobium sps.	0.14
Eriophyllum lanatum	0.16
Lotus sps.	0.26
Plagiobothrys figuratus	1.20
	0.20/second cut
Potentilla gracilis	0.10
Prunella vulgaris	0.02
Ranunculus occidentalis	0.31
Patch Grass/Forbs	
Elymus glauca	1.1
Grindelia integrifolia	0.55/bulk
Wyethia angustifolia	0.35/bulk
	0.19/second cut
Southwest Field: *Deschampsia* Wet Prairie Seeding	
Matrix Grasses	
Agrostis exarata	1.65
Deschampsia caespitosa	8.95

(Continued)

Note: On October 3, 1991, approximately 5.26 ha of the southeast field were seeded with the listed grass and forb species. On October 2, 1991, approximately 5.7 ha of the southwest field were seeded with the listed grass and forb species. All species were collected during the spring and summer 1991 except as noted.

Table 8 (Concluded)

Southwest Field: *Deschampsia* Wet Prairie Seeding	
Matrix Forbs	
Camassia quamash	1.79
Downingia elegans	0.84
Epilobium spp	0.14
Eriophyllum lanatum	0.16
Lotus spp	0.26
Microseris laciniatus	0.17
Plagiobothrys figuratus	1.20
Potentilla gracilis	0.16
Prunella vulgaris	0.04
Ranunculus occidentalis	0.31
Patch Grasses/Forbs	
Danthonia californica	0.05
Wyethia angustifolia	0.35/bulk
W. angustifolia	0.19/second cut

packing wheel to ensure even flow of suspension and maximum randomness. A harrow was hitched and dragged behind the seeder, ensuring good seed-soil contact.

c. *Method 3.* Fine seeded matrix forbs and *Deschampsia* grass seed were mixed by hand and seeded using the same procedure as described above, except they were not harrowed.

Woody plantings

Woody plant selection. The field inventory of vegetation found on existing West Eugene wet prairie fragments conducted in 1990 also included a survey of tree and understory shrub components of the Oregon ash, *Fraxinus latifolia*, and black cottonwood, *Populus balsamifera*, woodland communities and the prairie edge shrub community. These field data, compiled with previous studies[1] (SRI 1990) and an inventory of the donor site woody vegetation, were used to prepare a master plant list for the mitigation site. Thirteen

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[1] This information was compiled from the 1988 West Eugene Wetland field notes of Esther Lev.

Table 9
Tree and Shrub Plantings in the West Eugene Mitigation Site

Species	Type	Sector			NB	Total	% Total
		N	SW	SE			
Trees							
Black Cottonwood	C		275	125		400	20.3
Oregon Ash	SS	250	350	350		950	48.1
Willow	C	75	325	225		625	31.6
Tree Total		325	950	700		1,975	100.0
Shrubs							
Cascara	NS		13	21	10	44	1.4
Mock Orange	NS		15			15	0.5
Nootka Rose	NS		540		110	650	21.1
Red-osier dogwood	NS		755			755	24.5
Serviceberry	NS		353	126	65	544	17.6
Snowberry	NS		40	60		100	3.2
Spirea	NS		290	63		353	11.4
Willow	C	75	325	225		625	20.3
Shrub Total		75	2,331	495	185	3,086	100.0

Note: C = cutting; NS = nursery stock; SS = salvage seedling; NB = north buffer.

indigenous species were chosen including Oregon ash; black cottonwood; red willow, *Salix lasiandra*; piper's willow, *Salix piperi*; Sitka willow, *Salix sitchensis*; serviceberry, *Amelanchier alnifolia*; red-osier dogwood, *Cornus stolonifera*; western hazel, *Corylus cornuta*; Oregon hawthorne, *Crataegus douglasii*; osoberry, Oemleria cerasiformis; cascara, Rhamnus purshiana; Nootka rose, *Rosa nutkana*; and hardhack, *Spiraea douglasi*.

Woody plant acquisition. Native plant nurseries in the Pacific Northwest (from Southern Oregon to Southern B.C., Canada) were contacted regarding plant availability, prices, and their willingness to contract grow specified shrubs and trees. Using this information, the master plant list was revised, and a nursery in Southern Oregon was contracted to grow all woody plant materials specified, plus a 20 percent overage to be supplied if needed. The planting plan is shown in Figure 12. Two species, hazel and osoberry, were unavailable in 1991 due to poor reproduction. Substitutions for these plants were made with increased amounts of other species. A small number of plants was delivered for winter/spring 1990-91 planting in the N sector and the balance delivered for winter 1991-92 planting in the south sections.

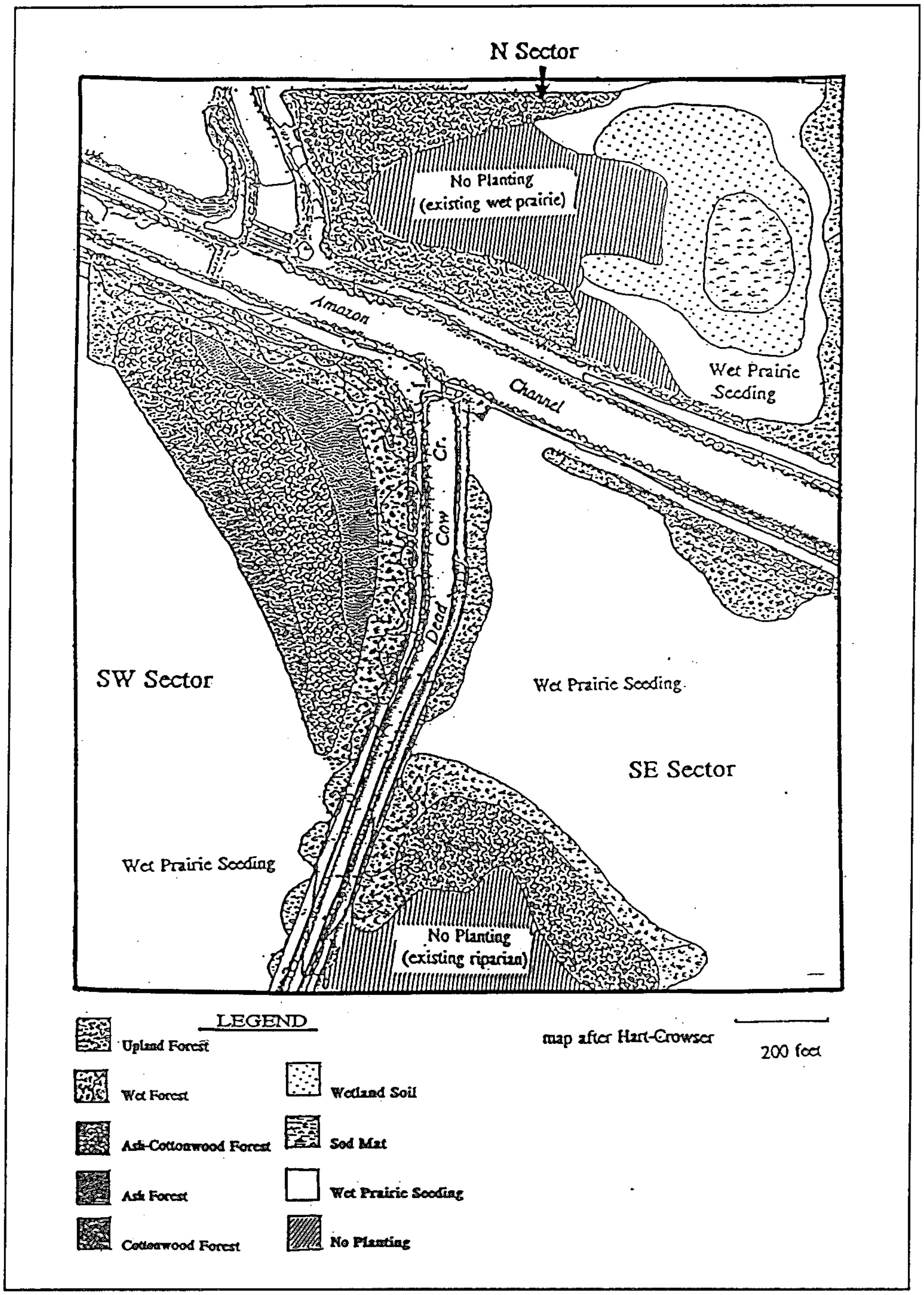

Figure 12. West Eugene Wetlands Research Project, planting plan

Woody plantings in the north sector: fall-winter 1990-91. On November 14, 1990, all the N sector wetland buffer areas were staked by the planting contractor and approved by the project horticulturist for planting according to the specified schedule (weather permitting). Container nursery trees and shrubs were planted in the N sector buffer on November 15. These plantings consisted of 65 serviceberry, 65 black hawthorne, 10 cascara, and 110 Nootka rose.

During the month of December, buds on ash, willow, and cottonwood at the donor site were checked to determine dormancy. By mid-January dormancy chilling temperatures had been achieved, and in February 1991, the planting contractor collected all required willow and cottonwood cuttings from the donor site and other West Eugene locations. Ash seedlings were salvaged from the donor site at Spectra-Physics. The cuttings and the bare root ash were then bundled and placed in cold storage at temperatures between 1 and 3 °C. Due to the extremely heavy spring rains of February and March, much of the area to be planted with forested wetland species was under several inches of water until early spring; the last cuttings and seedlings were planted on the mitigation site.

Woody plantings in the south fields: fall-winter 1991-92. Several modifications to the planting plan were made during the summer of 1991. Plant species and quantities needed to be adjusted due to crop failures at the nursery. Modifications were also made to planting locations due to site topography. As done in the N sector, plant locations were staked prior to planting. The amounts and species planted are listed in Table 10. The planting of specified woody shrubs on the south field berms and in the designated forested wetland areas began in late November 1991, and continued (as weather permitted) until April of 1992. Trees and shrubs were planted in areas without surface water or excessive soil saturation to prevent damage to the existing prairie understory. Container nursery plants were planted as weather conditions allowed.

In mid-January, bare root ash seedlings and cuttings of willow and black cottonwood were collected and placed in cold storage until they could be planted. Planting was delayed until April due to saturated soil conditions.

Maintenance

North field maintenance: summer-fall 1991

In the late spring of 1991, it became clear that maintenance of the N sector plantings would be necessary. North of the Amazon Dike, small patches of reed canarygrass were encroaching in areas seeded to tufted hairgrass and also had sprouted in the wetland sod areas. In mid-June and early August, Roundup herbicide was spot-applied to these areas.

In late June 1991, the planting contractor submitted an irrigation plan for N sector woody shrubs and trees to the project horticulturist for approval. This irrigation, while not required or specified by the planting contract, would ensure a high survival rate meeting plant warranty requirements for 80 percent survival (after 1 year). A combination of drip and flood irrigation techniques was utilized in order to water only woody materials and not the surrounding herbaceous wet prairie. In early July, after the willow cuttings exhibited water stress symptoms, irrigation was begun using water pumped from the

Amazon Channel. Thereafter, plants were watered once or twice monthly until mid-September.

By mid-summer, 1991, it was also observed that tufted hairgrass planting was not successful in depression areas of the N sector. This failure was ascribed to the prolonged ponding of surface water. In October of 1991, all of these areas were overseeded by hand with American sloughgrass, *Beckmannia syzigachne*, a wetland grass more tolerant of prolonged periods of inundation. After seeding, an ATV-drawn harrow was dragged to ensure soil-seed contact.

Monitoring

Monitoring was designed to document vegetative cover of grass and forb species and survival of woody species. Each sector was monitored by habitat type.

October 1990 - October 1991, N sector

Observations of plant growth in the sodmats during November and December 1990, 2 and 3 months after transplanting, showed that new growth was emerging. By early spring, the sodmats looked as lush and dense as they had on the donor site. Plant composition was diverse and dominated by indigenous species. Dominant species included one-side sedge, *Carex unilateralis*; creeping spikerush, *Eleocharis palustris*; penny royal, *Mentha pulegium*; tufted hairgrass, *Deschampsia caespitosa*; sloughgrass, *Beckmannia syzigachne*; and coyote thistle, *Eryngium petiolatum*. All species appeared to transplant well, including a couple of Oregon ash seedlings and some small willows. By mid-June the sodmat treatment averaged 92 percent cover.

At the same time in early spring, the wetland soil areas appeared barren; however, by early summer these areas had become verdant. Species were similar in composition to the sodmats but included more non-native species. Dominant species in this habitat included creeping spikerush, least spikerush, *Eleocharis acicularis*; common downingia, *Downingia elegans*; water plantain, *Alisma plantago-aquatica*; pointed rush, *Juncus oxymeris*; penny royal; and broad-leaf cattail, *Typha latifolia*. By mid-June the wetland soil treatment averaged 44 percent cover.

Limited germination and growth of tufted hairgrass in N sector areas seeded only with this species were observed during December before a hard freeze in January. Fortunately the freeze did not affect the young hairgrass plants. By the summer of 1991, tufted hairgrass clumps were growing well. Dominant vegetation in this habitat included tufted hairgrass, and nonplanted teasel, *Dipsacus sylvestris*; willowherb, *Epilobium paniculatus*; toadrush, annual ryegrass, and vetch, *Vicia* sp. The tufted hairgrass seeding averaged

20 percent cover by mid-June 1991. This low coverage was due to the tufted growth habit of the hairgrass as well as to depression areas that were too wet for tufted hairgrass to survive. The depression areas contained sparse vegetation dominated by downingia and popcorn flower.

October 1991 - October 1992

N sector. Monitoring during the second growing season for the N sector showed that sod mats are still the most successful treatment with 94 percent cover, a 2 percent increase over Year 1. Cover was natural and diverse and was expected to stay that way. The composition of vegetation was similar to Year 1. Vegetation cover was dominated by creeping spikerush and included American sloughgrass, beggar's tick, coyote thistle, mint, annual spikerush, and speedwell.

The wetland soil areas averaged 92 percent cover, a 48 percent increase over Year 1. Vegetation was dominated by creeping spikerush which, true to its name, expanded its cover by "creeping" into almost every available open space. Other species that occurred in at least half of the sample plots included pointed rush, annual spikerush, one-sided sedge, downingia, and water plantain. Vegetative cover contained a nice mix of native annual and perennial species.

The tufted hairgrass seeded areas still contained the least coverage, only 56 percent, an increase of 36 percent over Year 1. Vegetation was dominated by tufted hairgrass (33 percent cover) and Spanish clover. Other common species occurring on at least six plots included little quaking grass, velvet grass, toadrush, parentucellia, yellow hop clover, and vetch. Willowherb and toadrush, both aggressive colonizers, were common in this area during Year 1 but were not as conspicuous during Year 2. The depression areas within the hairgrass seeding contained little vegetation during Year 1. These areas were hand-seeded with American sloughgrass in the fall of 1991 because it can tolerate wetter conditions than tufted hairgrass. However, sloughgrass was not observed in these areas during Year 2. Vegetation cover in these low spots increased considerably due to the colonization of pioneer species such as downingia and popcorn flower.

SE sector. Vegetation monitoring in the SE sector was divided into three habitat areas: depression, nondepression, and lake. Depression areas are slight topographic low spots that retain ponded surface water through spring. These areas are scattered throughout the nondepression area that constitutes most of the northern half of the SE sector. The basin habitat is the excavated area in the west-central portion of the SE sector designated for ash forest.

After one growing season, the depression areas averaged 76 percent cover. Vegetation cover was dominated by downingia (52 percent) and included American sloughgrass (6 percent), popcorn flower (8 percent), and water plantain (7 percent). Four of the planted species were present including:

tufted hairgrass, sloughgrass, downingia, and popcorn-flower. Species with low cover but frequent occurrence included hedge-hyssop and reed canarygrass. The cover of reed canarygrass seemed insignificant, but it was present in nearly all of the depression area sample plots. The majority of reed canarygrass noted was large clumps; these plants grew from rhizomes that survived spraying and burning. They were protected from the burn by their location within the fireline prepared by the burn crew to prevent the fire from reaching the Amazon Dike. These clumps were treated with herbicide in September 1992. In October it was noted that young plants of reed canarygrass and had become established since the site was monitored in June; these plants germinated from seeds that were present in the seedbank or blown in from an adjacent site.

Vegetation cover in the nondepression areas averaged 92 percent and was dominated by toadrush (78 percent), tufted hairgrass (21 percent), and velvet grass (7 percent). Tufted hairgrass was present in every sample plot. A number of other species occurred in at least seven of the sample plots. These species included: downingia, sloughgrass, popcorn flower, velvet grass, parentucellia, bedstraw, and silver hairgrass. The abundance of velvet grass was probably due to the tufted hairgrass seed source which included 0.1 percent velvet grass.

The basin habitat of the SE sector contained 22 percent vegetation cover. This low percent cover was similar to the low percent cover found in the depression areas of the N sector in 1991. Surface water was present in this area for the longest duration, thus determining species survival. Downingia, a common colonizer in epheral ponds, dominates the vegetation (18 percent). Other species found in four or more sample plots included American sloughgrass, annual spikerush, tufted hairgrass, and toadrush. The tufted hairgrass was present along the lake margins.

Of the species that were planted, four occurred in sample plots: tufted hairgrass, American sloughgrass, popcorn flower, and downingia.

SW sector. The SW Sector was divided into two habitat areas for monitoring: depression areas and nondepression areas.

The depression areas averaged 99 percent coverage after one growing season. Vegetation cover was dominated by downingia (40 percent) and water foxtail (24 percent), and included tufted hairgrass (7 percent), mannagrass (8 percent), hedge-hyssop (10 percent), toadrush (9 percent), and popcorn flower (10 percent). Other frequently occurring species included silver hairgrass and popcorn flower.

Non-depression areas contained 99.8 percent vegetative cover. Vegetation cover was dominated by toadrush (85 percent) and ryegrass (29.4 percent). Other species occurring on at least half of the plots include tufted hairgrass (2.9 percent), downingia (.75 percent), velvet grass (0.3 percent), and parentucellia (0.2 percent).

Of the species that were planted, three occurred in sample plots: tufted hairgrass, downingia, and popcorn flower. Tufted hairgrass occurred in over half of the sample plots. One other species that was planted, buttercup, occurred in one sample plot.

Discussion

Transplanting sodmats and wetland soil has proved to be an effective wetland restoration technique. Transplanting minimizes invasive weed problems and reduces the expense of future vegetation maintenance programs. At the same time, species richness is maximized. Although it is always better not to destroy a native plant community, results indicate it is possible to move a native plant community when necessary when the right conditions are provided.

Establishment of prairie habitat in annual ryegrass and reed canarygrass is more problematic because it is necessary to first eradicate these exotic species. The herbicide/fallow treatment of annual ryegrass was effective at reducing ryegrass plants and depleting the seedbank. The percent cover of annual ryegrass decreased annually from 29 percent the first year, to 12 percent the second year and no trace by the third year after planting. While ryegrass cover decreased during the first year, annual native toadrush was dominant (82 percent). The ryegrass and toadrush concealed the shorter, small tufts of hairgrass (12 percent). By the third year, hairgrass tufts increased to 85 percent cover, and flower heads were approximately 5 ft tall; dominance shifted from an annual graminoid community to a perennial hairgrass dominated community.

The herbicide/burn treatment of the SE sector eliminated most pretreatment reed canarygrass plants; however, reed canarygrass continues to be invasive. Reed canarygrass rhizomes located on the north and lower end of the field survived the burn either because they were located within the firebreak or on the edge of the burn. These robust plants are a potential threat to the rest of the field as they spread through the growth of their rhizomes and production of seeds. Reed canarygrass must be monitored and controlled until it no longer threatens the establishment of the native prairie community. Ecological dominance in the SE sector has shifted from a perennial exotic grass to a perennial native hairgrass dominated community.

The combine harvest method for tufted hairgrass provided abundant and fairly inexpensive seed. Unfortunately, it was impossible to separate all of the velvet-grass seed from the tufted hairgrass seed. The seed used for planting contained 99.9 percent tufted hairgrass and 0.1 percent velvet-grass. Velvet-grass is a conspicuous non-native dominant in all of the hairgrass plantings. However, it appears to be a short-lived perennial; velvet-grass clumps have weakened and their cover has decreased from approximately 13 percent in 1993 to 3 percent in 1994. It is unfortunate that the contaminated seed was planted but it does not seem to pose a threat to wetland prairie establishment.

Attempts to restore native habitat must be tempered with patience and surveillance and management of invasive species. The ultimate composition of the plant communities in these fields will be a result of natural plant competition and succession as well as maintenance strategies.

Compared with wetland restoration planning, there are also contradictions inherent in wetland mitigation planning-driven permit conditions. The major contradiction is time: permit-driven mitigation projects are generally required to reach community composition goals within 3 to 5 years, allowing less than 1 year for site preparation. The Spectra-Physics project demonstrates that this may be too short a time frame, as exotic plants and seed bank still threaten the long term success of the wet prairie. The percent cover conditions of the permit can be met within 3 to 5 years, but the desired species composition of the plant communities, from a restoration viewpoint, probably will not be achieved in this short time.

The time factor is also important in restoration planning. The Spectra-Physics project suggests that woody species would not be planted until the ground layer is well established, allowing the use of fire, mowing, and/or herbicides for ground layer maintenance. Establishment of a stable ground layer community could take 5 to 10 years.

Conclusions

The sodmat and wetland soil transplants are to date the most successful treatments in terms of cover extent and rapidity. Vegetation in these areas looks natural, and composition is dominated by native species. These two treatments will probably require the least amount of maintenance during the next few years. The project goals for these treatment areas have been met.

The tufted hairgrass seeding in excavated areas of the N sector has been generally successful in terms of cover, although plant density has increased more slowly than in other areas. Large areas of tufted hairgrass flowered the second year. Tree and shrub seedlings and cuttings generally appear to be doing very well. Project goals in these areas have also been achieved.

The success of achieving project goals in the SE and SW sectors cannot be determined at this time. The plant communities in these fields are in a dynamic state, and species dominance continues to change. Many native grass and forb species have become well established in the SE sector and have produced large amounts of seed. Velvet grass was an early dominant; its position could change as other species increased in density and size. Reed canarygrass seedlings are common throughout the depression areas of the field, and time will tell whether or not this species becomes prevalent in certain areas. Trees and shrubs planted in the basin area are doing very well.

The SW sector was dominated during the first year by toadrush, as well as native forbs. Growth of tufted hairgrass during the second year (1992-1993) will be more evident in terms of species cover. Tree and shrub plantings could not be assessed due to drought conditions.

Monitoring of these plantings will continue through 1994. A maintenance program is also being discussed to control invasive, weedy species until the desired species have achieved dominance.

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Appendix A
Master Plant Species List for West Eugene Wetland Project

Abbreviation	Scientific Name	Common Name	Form
AG AL	*Agrostis alba*	redtop	PIG
AG EX	*Agrostis exarata*	bentgrass	PNG
AG SP	*Agrostis* sp.	bentgrass	
AI CA	*Aira caryophyllea*	silver hairgrass	AIG
AL PL	*Alisma plantago-aquatica*	water plantain	PNF
AL GE	*Alopecurus geniculatus*	water foxtail	PNG
AL PR	*Alopecurus pratensis*	meadow foxtail	PIG
BE SY	*Beckmannia syzigachne*	American sloughgrass	ANG
BI CE	*Bidens cernua*	nodding beggar's tick	ANF
BI FR	*Bidens frondosa*	beggar's tick	ANF
BO DE	*Boisduvalia densiflora*	dense flower spike-primrose	ANF
BO GL	*Boisduvalia glabella*	smooth spike-primrose	ANF
BR MI	*Briza minor*	little quaking grass	AIG
BR CO	*Bromus commutatus*	hairy brome	AIG
CA PE	*Cardamine penduliflora*	Willamette Valley bittercress	PNF
CA UN	*Carex unilateralis*	one-sided sedge	PNG
CE MI	*Centunculus minimus*	chaffweed	ANF
CE MU	*Centaurium muhlenbergii*	Monterey centaury	PNG

(Sheet 1 of 3)

Note: A = annual; P = perennial; I = introduced; N = native; G = grammoid; and F = forb.

(Continued)			
Abbreviation	**Scientific Name**	**Common Name**	**Form**
CE UM	*Centaurium umbellatum*	centaury	AIF
CH LE	*Chrysanthemum leucanthemum*	oxeye daisy	PIF
CI AR	*Cirsium arvense*	Canada thistle	PIF
DA CA	*Danthonia californica*	California oatgrass	PNG
DAUC	*Daucus carota*	Queen Anne's lace	AIF
DE CA	*Deschampsia cespitosa*	tufted hairgrass	PNG
DE DA	*Deschampsia danthonioides*	annual hairgrass	ANG
DI SY	*Dipsacus sylvestris*	teasel	AIF
DO EL	*Downingia elegans*	downingia	ANF
DO YI	*Downingia yina*	downingia	ANF
EL AC	*Eleocharis acicularis*	least spikerush	PNG
EL PA	*Eleocharis palustris*	creeping spikerush	PNG
EP PA	*Epilobium paniculatum*	willowherb	ANF
EP WA	*Epilobium watsoni*	Watson's willowherb	PNF
ER PE	*Eryngium petiolatum*	coyote thistle	PNF
ER LA	*Eriophyllum lanatum*	woolly sunflower	PNF
FE AR	*Festuca arundinacea*	tall fescue	PIG
FE BR	*Festuca bromoides*	barren fescue	AIG
FR LA	*Fraxinus latifolia*	Oregon ash	
GA TR	*Galium trifidum*	bedstraw	PNF
GE MO	*Geranium molle*	gernaium	AIF
GL OC	*Glyceria occidentalis*	western mannagrass	PNG
GN PA	*Gnaphalium palustre*	lowland cudweed	ANF
GR EB	*Gratiola ebracteata*	bactless hedge-hyssop	ANF
HO LA	*Holcus lanatus*	velvet grass	PIG
HO BR	*Hordeum brachyantherum*	meadow barley	PNG
HY PE	*Hypericum perforatum*	Klamath weed	PIF
HY RA	*Hypochaeris radicata*	hairy cats-ear	PIF
JU BU	*Juncus bufonius*	toadrush	ANG
JU OX	*Juncus oxymeris*	pointed rush	PNG
JU TE	*Juncus tenuis*	slender rush	PNG
LO MU	*Lolium multiflorum*	annual ryegrass	AIG
LO PU	*Lotus purshiana*	Spanish clover	ANF
			(Sheet 2 of 3)

(Concluded)

Abbreviation	Scientific Name	Common Name	Form
LU PA	*Ludwigia palustris*	marsh purslane	PNF
LY NU	*Lysimachia nummularia*	creeping Jenny	PIF
MA EL	*Madia elegans*	tarweed	ANF
ME PU	*Mentha pullegium*	pennyroyal	PIF
MI GR	*Microsteris gracilis*	pink mirosteris	ANF
MI QU	*Microcala quadrangularis*	timwort	ANF
MY DI	*Myosotis discolor*	forget-me-not	AIF
MY LA	*Myosotis laxa*	forget-me-not	PNF
NA IN	*Navarettia intertexta*	needle-leaf navarettia	ANF
OR BR	*Orthocarpus bracteosus*	rosey owl-clover	ANF
OR HI	*Orthocarpus hispidus*	hairy owl-clover	ANF
PA CA	*Panicum capillare*	witch-grass	ANG
PA VI	*Parentucellia viscosa*	parentucellia	AIF
PH AR	*Phalaris arundinacea*	reed canarygrass	PIG
PL FI	*Plagiobothrys figuratus*	fragrant popcorn flower	ANF
PL SC	*Plagiobothrys scouleri*	Scouler's popcorn flower	ANF
PO AV	*Polygonum aviculare*	prostrate knotweed	AIF
PO PO	*Polygonum polygaloides*	knotweed	ANF
PR VU	*Prunella vulgare*	self-heal	PNF
RA OC	*Ranunculus occidentalis*	western buttercup	PNF
RA OR	*Ranunculus orthorhynchus*	straight-beaked buttercup	PNF
RO CU	*Rorippa curvisiliqua*	curve-pod yellowcress	ANF
RU AC	*Rumex acetosella*	sour dock	PIF
RU CR	*Rumex crispus*	curly dock	PIF
TR DU	*Trifolium dubium*	yellow hop clover	AIF
TR SP	*Trifolium* sp.	clover	PIF
TY LA	*Typha latifolia*	broad-leafed cattail	PNF
VE BL	*Verbascum blattaria*	moth mullein	AIF
VE PE	*Veronica peregrina*	purslane speedwell	ANF
VE SC	*Veronica scutellata*	marsh speedwell	PNF
VI SP	*Vicia* sp.	vetch	IF

(Sheet 3 of 3)

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Native plants are desirable materials for wetland establishment because they are diverse and adapted to local environments. While information is readily available for commercially available plant material, little information is available about plant material collected from native wetlands. The objectives of this report are to discuss conditions under which it is appropriate to use native sources of plant material and to present three case studies that demonstrate techniques for collection of establishment of native wetland plant material. Advantages and disadvantages of using native versus commercially available plant material are discussed. Guidance is provided for collecting and handling native plant materials. The case studies illustrate several handling techniques. Case Study #1 is from a reservoir called L-Lake on the Savannah River Plant in South Carolina. Native plants were collected from a nearby reservoir and planted in appropriate hydrologic zones along the L-Lake shoreline. Case Study #2 demonstrates the use of wetland organic soils as topsoil to rapidly establish diverse vegetation in a created wetland located in Charlotte County, Florida. Case Study #3 uses a variety of methods including seed collection, transplants, and sodmat transfers to establish native vegetation of an endemic wet prairie community near Eugene, Oregon.

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